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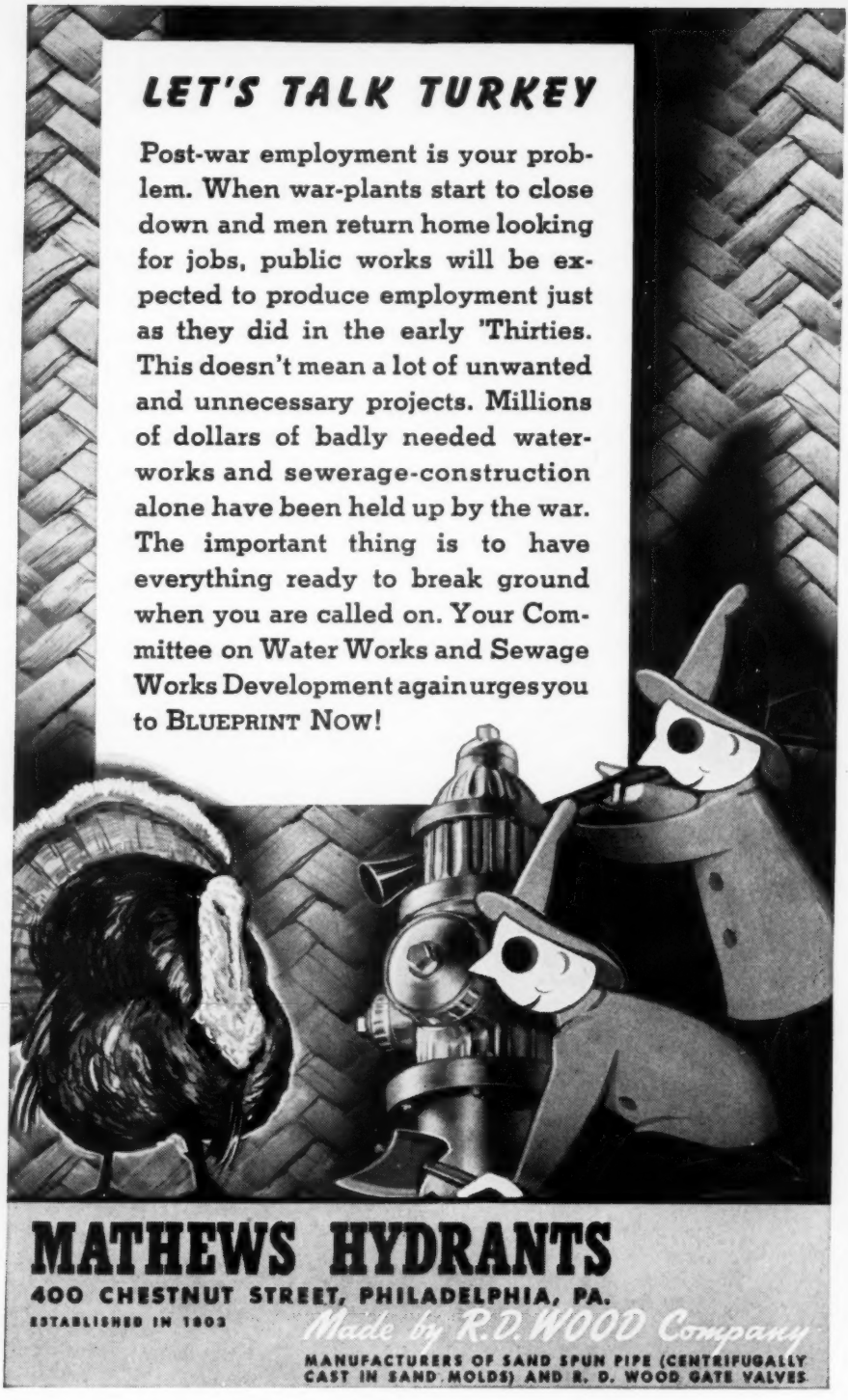
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ENDS TASTES AND ODORS AT BALTIMOR

PERSISTENT tastes and odors at Baltimore's Lake Ashburton distribution reservoir have been brought to an end by continuous chlorination of the entering water to maintain a high residual in the water beneath the surface. Organic deposits on the rough bottom "could not be cleaned out." But now they are "blanketed" by the high residual in the lower strata of water and no longer affect taste and odor of the finished water.

Gordon L. O'Brien, Designing Engineer, Baltimore Bureau of Water Supply reports*: "This system has been so effective that we have adopted it in our other reservoirs where circulating lines exist."

Previously, only the reservoir effluent was chlorinated. Now the effluent needs only a small amount of chlorine to maintain a residual of at least 0.5 ppm in the mains.

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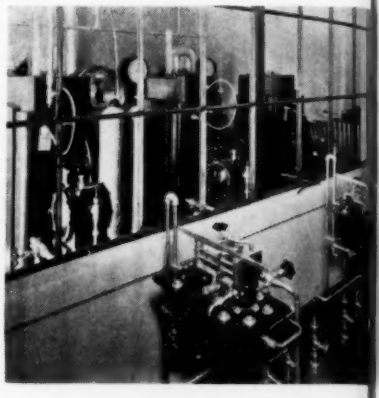

*"Taste and Odor Control by Reservoir Chlorine Blanket" by Gordon L. O'Brien, Designing Engineer, Bureau of Water Supply, Baltimore, Md. Water Works Engineering, Vol. 96 No. 18. A reprint of this article is yours for the asking.

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Vol. 36 November 1944 No. 11

Recovery of Calcium Carbonate or Lime From Water Softening Sludges

By Robert T. Sheen and Herbert B. Lammers

THE problem of disposal or utilization of sludges resulting from water softening has long held the interest of water works operators and those interested in water treatment problems. Aultman (1) recently reported in detail the studies made on sludge produced from softening Colorado River water and a rather complete bibliography is appended to that paper. Tests on the Lykken-Estabrook process are reported wherein a split treatment is employed. The dewatering of sludge in order to eliminate build-up of undesirable magnesium salts by use of a vacuum filter was proposed. Hoover (2) has also proposed a two-stage process in which the first step is to precipitate the calcium only. The next step is to collect the resulting sludge for treatment and burning and precipitate magnesium in a separate tank with the addition of further treatment chemicals. Sowden (3) has reported on studies on the sludge from the Minneapolis water softening plant, which readily indicate the difficulties that can be anticipated with succeeding calcinations where magnesium and other inerts are not removed from the sludge. A vacuum filter is here again suggested for sludge dewatering. Sowden reported that it was not possible to obtain a moisture content of less than 55 per cent on a vacuum filter operation and better results were obtained when no coagulant was used in the softener.

Some of the difficulties of disposing of sludges by ponding are discussed by Dittoe (4). A patent (5) was recently granted for treatment of calcium carbonate sludges by application of sodium carbonate and the formation of a double salt of the carbonate.

Until recently, there has been no plant of appreciable size in this country where water softening sludges have been successfully handled on a commercial scale, either for the recovery of calcium carbonate in a purified form

A consolidation of a paper presented at the Ohio Section Meeting, Columbus, Ohio, May 18, 1944, and a paper presented at the Milwaukee Conference on June 14, 1944, by Robert T. Sheen, Assoc. Director, Cons. Div., W. H. & L. D. Betz, Philadelphia, Pa.; and Herbert B. Lammers, Asst. Plant Engr., Wright Aeronautical Corp., Cincinnati, Ohio.

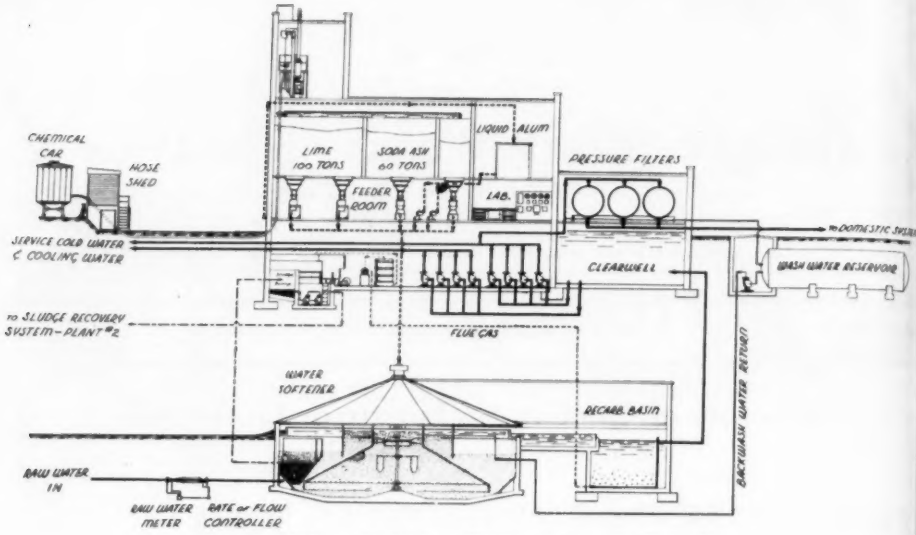

FIG. 1. Water Softening Plant 1—8-mgd. Capacity. Wright Aeronautical Corp., Cincinnati, Ohio.

or for the purification of calcium carbonate to such an extent that lime burning could be considered practical. There is an installation in England at the Southend Water Works Co. at Langford (6, 7), where the use of a water of low magnesium content makes possible reburning and re-use of the lime. There is one industrial plant in this country at a paper mill where lime from the water softening process is reburned along with liquors from the paper mill for lime recovery, but in this case the water softening sludge forms a small portion of the total.

Lime-Soda Softening and Sludge Disposal at Wright Aeronautical Corp.

When the Wright Aeronautical Corp. decided to locate an aircraft engine plant at Cincinnati, it was immediately recognized by the engineers in charge of the project that the available water supply and its quality would require careful study, due to enormous water requirements and the processes in which the water would be utilized.

For this one industrial plant the water requirements are equivalent to those of a city with a population of 200,000, and the water delivered to the plant must not only equal but must in many ways be superior to a city water in chemical and bacteriological purity because of the industrial processes in which this water is required.

Because of the poor quality of the raw water available to the plant and the specifications of the required finished water, two water treatment plants with a number of unusual design features were installed. The first one was designed for a capacity of 8 mgd., to take a raw water supply from six 1,000-gpm. deep wells located on the property (Fig. 1). The well waters were found to vary in hardness from 282 to 671 ppm., and in iron content from 2.5 to 8.5 ppm. Such a large variation in the hardness of several wells all located on the same property is

most unusual, and this variation in hardness was found to continue with continued use and pumping.

When the first water treatment plant was completed (Figs. 2, 3), it was decided to expand the facilities for production about 350 per cent. A second water treatment plant with a capacity of 14 mgd. was constructed to meet this expansion. It was recognized that the capacity of the wells on the property, together with additional wells that might be located, would not be sufficient to meet this water requirement, and a federal project was undertaken to bring raw water from the Miami Valley to the plant. The hardness and mineral content of the new supply was found to be less than that of the water from the wells at the plant, with an average total hardness of from 300 to 370 ppm. and a low iron content.

It was estimated that of the total requirements of the plant, 25 per cent of the water would be required for domestic consumption and sanitary purposes and the remaining 75 per cent for industrial purposes, in acetylene generation, pickling, heat treatment, plating, dynamometer, engine testing, paint and baffle shop, gasoline system,

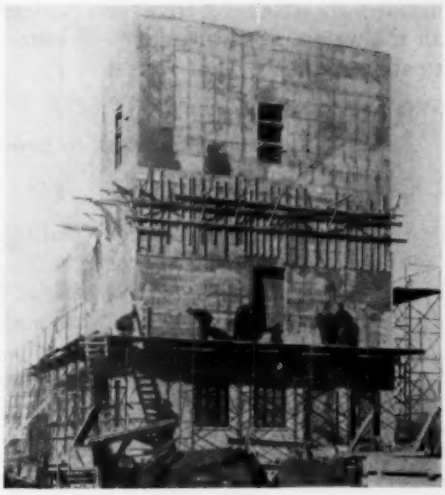

FIG. 2. Water Treatment Plant 1 During Construction.

air and gas coolers, anodize and dichromate, oil and chip house, boiler house, rotoclones, x-ray developing baths and a number of miscellaneous heat-exchange processes throughout the plant. Many of these uses for water are critical, and it was imperative that deposition of solids in the many points of heat exchange be prevented and that the solids in the water should not interfere with the various chemical processes or plating. It was

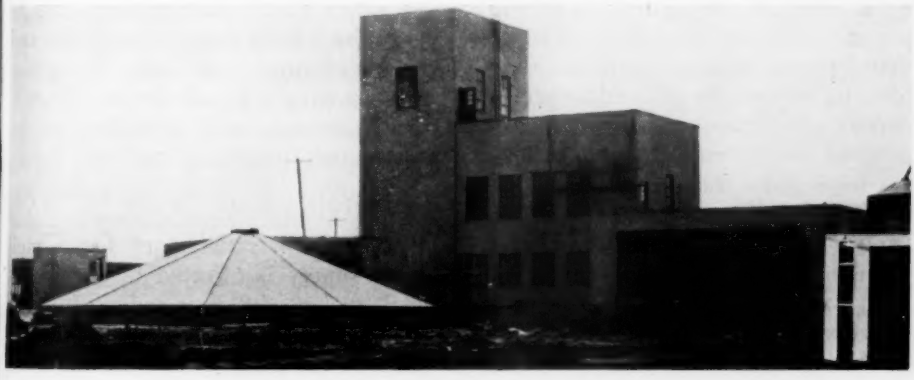

FIG. 3. Water Treatment Plant 1.

decided therefore to treat and soften all the water. The objectives of water treatment at this plant were to:

1. Minimize corrosion.
2. Reduce calcium hardness to prevent calcium carbonate scale.
3. Reduce iron content.
4. Provide a stable water, neither scale-forming nor corrosive.
5. Provide a sterile water, satisfactory for drinking purposes, and eliminate the necessity for a complicated piping system that would be required for treating only part of the total water utilized.

To Minimize Corrosion

The well water as received has a considerable content of carbon dioxide, and this, together with any dissolved oxygen picked up in contact with the air, could cause considerable corrosion. Dissolved oxygen must be held at a minimum concentration and the pH value of the treated water must be maintained at that point where calcium carbonate will neither deposit nor have a tendency to dissolve or to permit corrosion due to a low pH value.

To Reduce Calcium Hardness

Except when used for boiler feed, water in which magnesium hardness is present is not objectionable. The primary reason for softening is, therefore, to remove the calcium to prevent deposition of calcium carbonate and to prevent interference by the calcium hardness with the various processes. Selective calcium softening by proper control of the pH value was utilized to reduce the calcium hardness only. The magnesium hardness was allowed to remain in solution. The application of this principle has been previously reported by Sheen and Woodruff (8). Selective calcium softening results in a considerable saving in chemical cost. The softening reaction is controlled at a pH value of 9.6 to 9.8, followed by recarbonation to a pH value of 8.6, a point at which no magnesium may be expected to leave solution at any point in the process or in the distribution system.

To Reduce Iron Content

It is desirable to reduce the iron in the water to a minimum. It is known from experience that iron in excess of 0.3 ppm. will stain sanitary fixtures, cause iron deposits to form in piping and distribution systems and interfere with operations such as plating, x-ray work and special processes. Selective calcium softening with maintenance of pH value at 9.6 will effectively precipitate iron and deliver a water with an iron content of not more than 0.05 to 0.1 ppm.

To Provide a Stable Water

It is desirable to distribute a water throughout the system that will neither deposit calcium carbonate nor re-dissolve any calcium carbonate that may be present on surface films; in other words, to deliver a water that will be stable in accordance with the Langelier Index (9). This stability can be determined from chemical analysis and the application of the Langelier formula with a knowledge of the calcium hardness, total dissolved solids, temperature, alkalinity and pH value.

To Provide a Sterile Water

Sterilization satisfactory for a well water supply is effected by treatment of all water with lime-soda softening. Hypochlorite feeding apparatus is provided in the plant for use at any time that an unusually high bacteria count

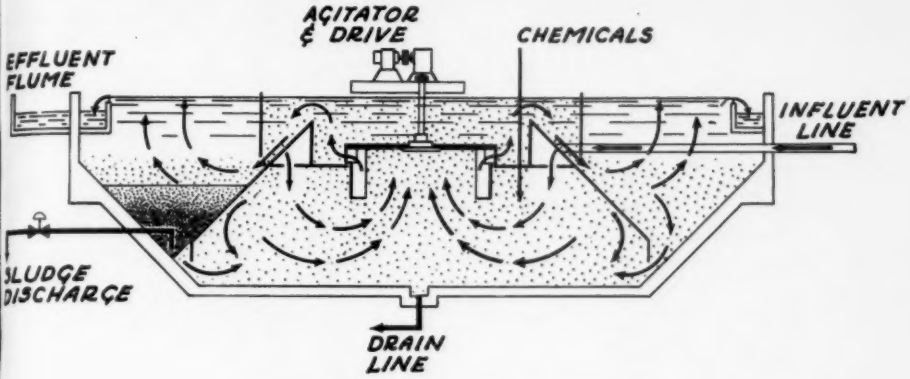

FIG. 4. Schematic Drawing of Accelator.

makes it necessary to supplement the sterilization derived from the lime-soda softening.

Water Softening Plant Design

Table 1 shows design data for the water softening plants, which are of the accelator type. The incoming raw water is mixed with a slurry of sludge, previously precipitated, and is also mixed with the softening chemicals in the presence of the previously formed sludge (Fig. 4). The slurry, water and chemicals are mixed by the agitator under the hood. A portion raised by the agitator in the center compartment of the softener is allowed to flow down over the hood where a separation of clarified and softened water from the circulating slurry is effected, the clarified water rising and flowing over the effluent weir. A portion of the circulating slurry returns under the hood and a portion flows into sludge concentration compartments from which it is removed automatically on a timed cycle every 5 min.

The turbidity of the effluent water from the softeners has consistently been maintained at approximately 1 to 3 ppm. The desired rate of flow through the softening plant is determined by the operator and set on the rate-of-flow controller on the raw water line at such a rate as to hold a relatively constant level in the clear well.

Duplicate chemical feeders have been furnished for each chemical at each plant. An appreciable variation, running as high as 10 per cent, was found in the quantity of lime delivered by the volumetric feeders in Plant 1. The volumetric soda ash feeders in that plant were found to be quite consistent in the weight of chemical delivered per unit of time. In order to effect more exact control of the lime, it was decided to equip Plant 2 with gravimetric feeders, the extra expense being justified by the large volume of water treated.

Some difficulty was experienced with the orifice type of feeder for liquid alum, due primarily to the insolubles present in the liquid alum as delivered. A decanting type of feeder was therefore selected for Plant 2.

Plant 1 was originally designed to handle alum in crystalline form. It was learned that an appreciable saving could be effected by buying liquid alum, because it is manufactured at several plants relatively close to the

TABLE 1

Design Data for Water Softening Plant
Wright Aeronautical Corp.

SOFTENING BASIN AND CHEMICAL FEEDERS

	Plant 1	*Plant 2*
Softening basin, upflow type, accelator by Infilco, basin dimensions	60-ft. diam. 18 ft. deep	75-ft. in diam. 21 ft. deep
Rated capacity of softening basin, *gpm*	5500	9500
Softening basin, rated rise rate in outer chamber, *gpm./sq. ft.*	2.5	2.74
Softening basin, minimum retention at maximum rating, *min.*	61	60
Horsepower of motor on agitator drive, *hp*	10	15
Continuous lime feeders and slakers, Infilco	Volumetric, dry to slaker	Gravimetric, dry to slaker
Lime feeders, capacity, *lb./hr.*	2 @ 750	2 @ 1500
Soda ash feeders	Volumetric, dry	Gravimetric, dry
Capacity, *lb./hr.*	20 to 800	20 to 500
Liquid alum feeders, type	Constant head over orifice	Decanting
Liquid alum feeders, capacity dry alum, *lb./hr.*	20 to 150	27 to 270
Raw water inlet rate-of-flow control system	16-in. hydraulically operated valve manually set for rate	24-in. butterfly valve controlled at meter panel

FILTERS

	Plant 1	*Plant 2*
Number of filters	3	8
Type	Pressure	Gravity
Dimensions	8 ft. diam. 25 ft. long	14 ft. 8 in. wide 30 ft. long
Total filter area, *sq. ft.*	525	3520
Design capacity at 3 gpm. per sq. ft., *gpm.*	1575	10,560
Filter bottom design	$\frac{3}{8}$-in. stainless steel strainers on $1\frac{1}{2}$-in. laterals feeding to 8-in. header. Total 673 strainers	Wheeler bottom
Filter medium	Anthracite coal	Anthracite coal
Particle size, top layer, 27 in. deep, *mm.*	0.7 to 0.8	0.7 to 0.75

RECARBONATION SYSTEM

Size of basin	19 ft. wide, 19 ft. long, 14 ft. deep	17 ft. wide, 30 ft. long, 15 ft. deep
Capacity of basin, *gal.*	38,000	95,000
Retention at maximum flow, *min.*	6.9	10
Oil burner, gases for recarbonation, capacity of burner, *gal./hr.*	8	10
CO_2, estimated maximum demand, *lb./hr.*	100	150
CO_2, average in flue gas, %	6 to 8	6 to 8
Compressor, capacity, *cu.ft./min.*	150	250

TABLE 1—*Continued*

PNEUMATIC CHEMICAL UNLOADING EQUIPMENT AND BULK CHEMICAL STORAGE

	Plant 1	*Plant 2*
Pneumatic unloading system, design by	Fuller Co.	Dracco Co.
Rated capacity, pebble lime, *tons/hr.*	7½	7½
Lime bin, size	22 ft. long, 12 ft. wide, 15 ft. deep	40 ft. long, 12 ft. wide, 19 ft. deep
Lime bin, capacity, *tons*	100	240
Soda ash bin, size	17 ft. long, 12 ft. wide, 15 ft. deep	30 ft. long, 8 ft. wide, 19 ft. deep
Auxiliary soda ash bin, size	8 ft. long, 12 ft. wide, 15 ft. deep	
Soda ash bin, capacity, *tons*	60	80
Auxiliary soda ash bin, capacity, *tons*	25	
Liquid alum tank, size	8 ft. diam. 12 ft. deep	2 @ 8 ft. diam. 19 ft. deep
Liquid alum/tank, capacity, *gal.*	4500	14,300
Alum storage, alum at 4.35 *lb./gal.*	19,500	62,300
Calcium carbonate bin (Plant 2 only)		30 ft. long, 15 ft. wide, 24 ft. deep
Calcium carbonate storage capacity at 50 lb. per cu.ft., *tons*		250

plant to meet the demand for its use by paper manufacturers. The storage bin, originally planned for alum, is therefore used for soda ash as auxiliary storage.

The Venturi meter in the raw water line to the softener at each plant is used not only to record the flow, but also to actuate the flow controllers and the chemical proportioning system which proportions the quantity of chemicals fed the softener to the flow of water entering the softener.

Pneumatic Chemical Unloading Equipment and Bulk Chemical Storage

A study was made of the several types of conveying systems that might be employed for each of the plants, and the pneumatic type of system was found to offer the greatest flexibility and promised to be the most satisfactory. The possible disadvantages of higher power requirements and additional head room for the pneumatic receiver are offset in each case by the flexibility of the system and the fact that in Plant 1 it was necessary to bring the chemicals from a rail siding underneath a road up to the storage bin. In Plant 2 the same pneumatic system that is designed for unloading the lime and soda ash is connected with a suction line to the calcium carbonate bins to draw from those bins when desired and to load bulk cars of calcium carbonate for the customers who may desire delivery in that form. In Plant 1 the lime and soda ash bins are fed by a common screw conveyor from the pneumatic receiver, the operator being responsible for seeing that the proper slide gates are open to discharge the chemical to its respective bin. In Plant 2 there is a gate on the pneumatic receiver to direct the discharge from the receiver to a screw conveyor on the lime bin or on the soda ash bin as may be required.

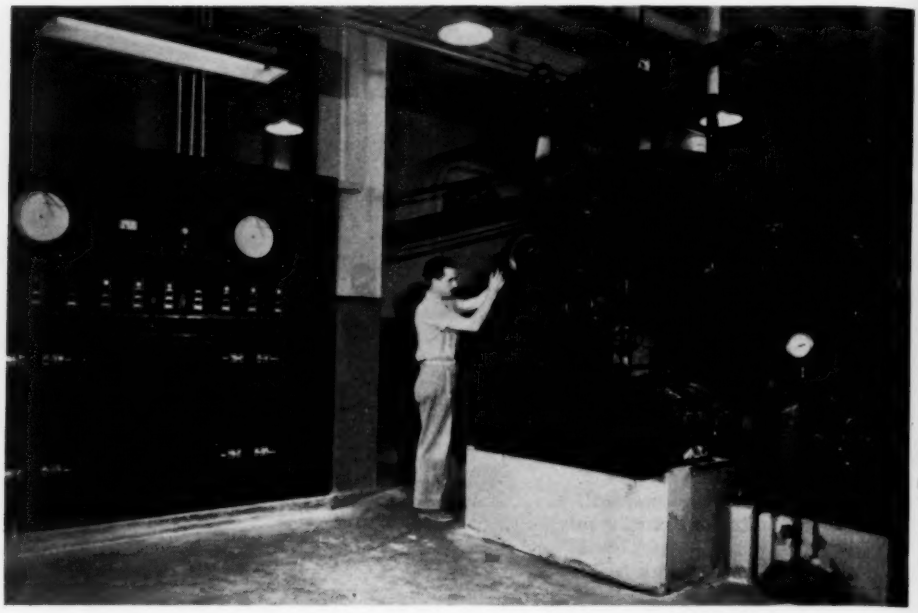

FIG. 5. Recarbonation Flue Gas Scrubber and Panel Board on Calcium Carbonate Drying System.

Recarbonation System

In Plant 1 a low-pressure boiler (25 hp.) is used to produce flue gas for recarbonation process and steam for heating and hot water. During the summer the excess steam is exhausted to the atmosphere. A Foxboro Ratio Stabilog controller is employed to proportion automatically the flow of flue gas to the recarbonation basin to the flow of raw water entering the plant. The orifice in the raw water line actuates this controller for the purpose of establishing this ratio.

In Plant 1, a two-point Leeds & Northrup pH recorder is used to record both the pH value of the circulating slurry in the softener basin and the pH value of the water in the recarbonation basin. An indication and continuous record of these pH values are of importance not only for the proper control of the selective calcium softening process but also for the assurance of recarbonation to the pH desired for a stable water.

In Plant 2, a slightly different system is employed for control. Both the flow of raw water to the plant and the flue gas are metered with a Bailey meter. The flow of flue gas is ratioed to the flow of raw water (Fig. 5). In addition to this, the pH value of the water in the recarbonation basin is measured by a Leeds & Northrup meter which actuates a controller that regulates automatically the ratio of flue gas to raw water. Some difficulty was experienced in the operation of Plant 1 due to the varying carbon dioxide content of the flue gas and the difficulty of holding the carbon dioxide content constant in such a small boiler system. It was for this reason that this system was adopted for Plant 2.

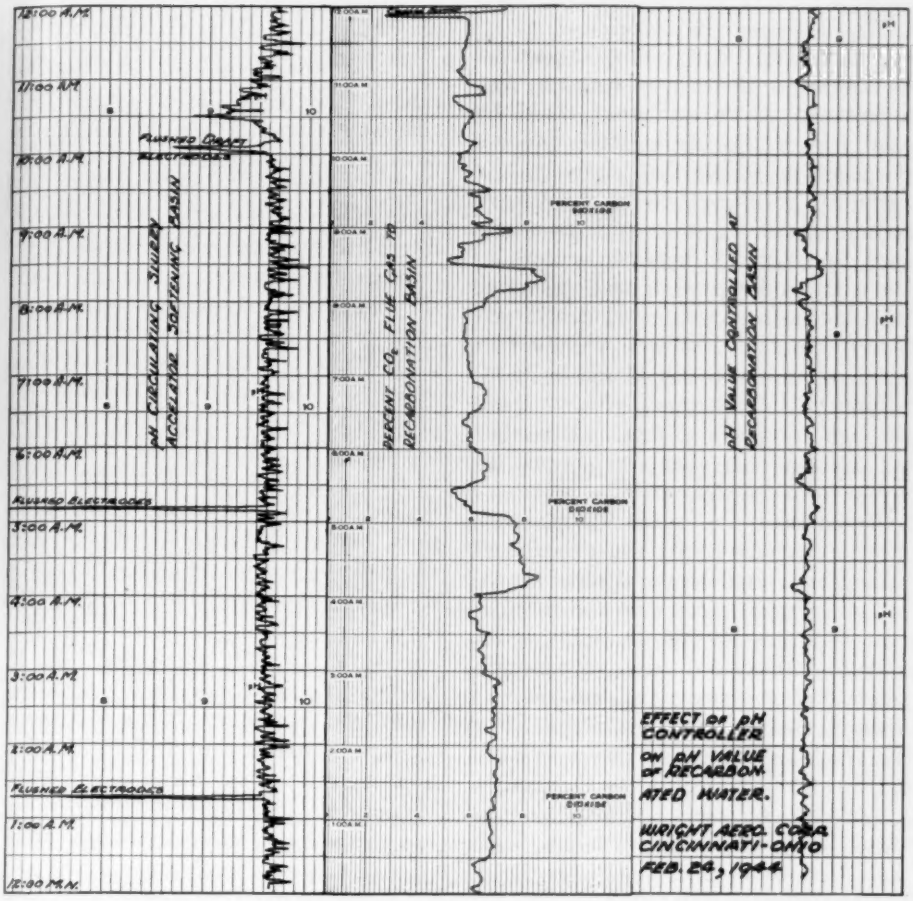

FIG. 6. Three Meter Records Showing Effect of pH Control on pH Value of Recarbonated Water.

Figure 6 illustrates the value of this control. Shown is a typical section of the charts from the two pH meters and the CO_2 meter covering a period of 12 hr. on Feb. 24, 1944. The pH value of the water from the softener shows a normal variation of approximately 0.3 with a strong dip at 10:30 A.M. Control of combustion in the furnace of Plant 2 was apparently difficult during this period, as a variation in several points is shown in the CO_2 between 4.5 to 8.5 per cent, with one dip to as low as 2.5 per cent. In spite of this variation in CO_2, with some variation in the pH value of the water in the softener, the pH value in the recarbonation basin (held by means of the controller) shows a maximum deviation of 0.3, holding most of the time within 0.1, at a pH value of 8.7. This automatic pH control therefore eliminates the necessity for careful manual adjustment and will hold the pH value at the desired point to maintain a stable water.

Filters

At the time Plant 1 was designed, a dual piping system was planned so that a softened water unfiltered could be used for certain cooling and process purposes in which the relatively low turbidity resulting would not prove objectionable. It was considered necessary to filter all domestic water, so Plant 1 was designed to have the water that had been recarbonated discharged directly to the clear well. Only that portion required for domestic consumption is pumped from there through pressure filters. All other service water supplies are pumped directly from the clear well.

When Plant 2 (Fig. 7) was planned, it was calculated that the expense of providing a dual piping system would be considerably more than the installation of filters for all the water, and, with the other advantages of having a single piping system, the decision was made to filter all softened water. For this reason, gravity filters were selected and installed to operate as twin units, a total of eight filters operating as four twins, with four control tables, each equipped with loss-of-head and rate-of-flow gages for the individual filters, and each filter equipped with effluent rate-of-flow controllers. Anthracite coal was selected as a filter medium in both plants in order to save on backwash water requirements and to avoid incrustation of the filter. The gravity filters are equipped with Palmer Filter Sweeps, two sweeps to each filter, and they have proved of considerable assistance in maintaining clean filters.

In Plant 1, a backwash line is provided with a meter to indicate the amount of water being used for this purpose. In Plant 2 a backwash rate-of-flow controller and indicator is installed. A backwash rate of 10 to 11 gpm. per sq. ft. is employed. In each plant the backwash water is collected in a storage tank and bled back to the softening basin at a low rate, so that this water is fully recovered and all sludge accumulated is finally removed from the softening basin. Normal filter runs average from 7 to 10 days and the filters are backwashed when loss of head reaches 6 ft. Due to the low turbidity of water discharged from

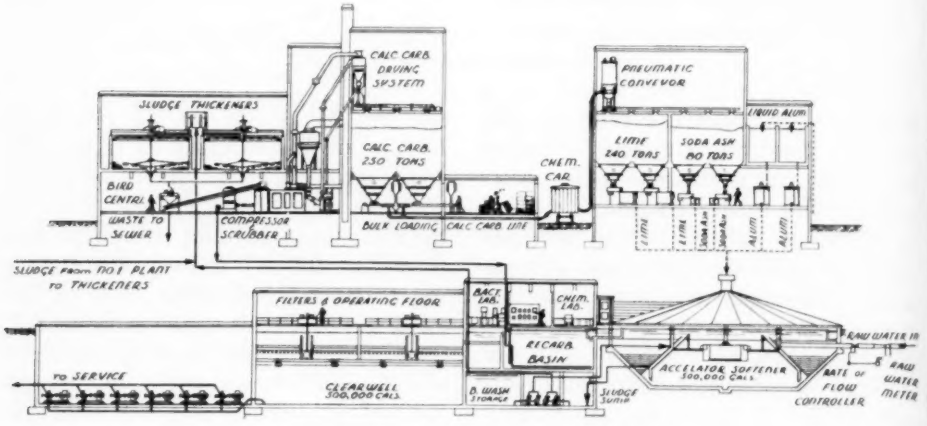

FIG 7. Water Softening Plant 2—14-mgd. Capacity. Wright Aeronautical Corp., Cincinnati, Ohio.

the softener to the filters, averaging 3 ppm., the water required for backwash purposes is only 0.3 per cent of the water filtered. Filtered water is discharged directly to a 500,000-gal. clear well located below filters and pipe gallery in Plant 2 and pumped from there to the elevated storage tanks and to service.

Meters and Controls

With the exception of the sludge drying system and the filter meters and controls, meters for the water treatment plant are centralized on a single panel located in the laboratory of the water softening plant, under the constant eye of the operator. In Plant 1 the waters metered on the indicating, recording and totalizing instruments include the raw water to the plant, cooling water, cold and domestic water. In Plant 2, the waters metered include the raw water to the plant and the treated water from the plant. In each plant the percentage of CO_2 in the flue gas is indicated and recorded along with the flow of flue gas in cubic feet per minute. In Plant 1, the pH value of the water in the circulating zone of the softener and the water from the recarbonation basin is recorded on a two-point meter. In Plant 2, the pH value of the water in the softening basin is indicated and recorded. The pH value of the water in the recarbonation basin is separately indicated and recorded and used to control the flow of flue gas as previously described. Liquid levels in clear wells and elevated storage tanks are indicated and recorded, and these meters are furnished with suitable high- and low-level alarms. The level of water in the backwash storage basin is indicated for the guidance of the operator responsible for backwashing the filters.

The recording pH meters serve as the heart of the chemical control on the softening process. Routine chemical tests are made on the raw water supply, accelator softener effluent, recarbonated and filtered waters. A complete log of operations is maintained, together with daily data sheets covering meter readings, chemical consumption and other pertinent data.

Dewatering Sludge

When the first plant was planned time did not permit a study or exhaustive review of possible methods of sludge disposal, although it was immediately recognized that this problem existed. The need for the water treatment plant, along with the other industrial facilities for aircraft engines, made it imperative to proceed with the design, with temporary provision for ponding the sludge until it could be determined what method should be employed for ultimate disposal. Shortly after Plant 1 was completed and in operation, studies and pilot plant tests were finished and a decision made concerning the system to be employed for sludge treatment and disposal. This system became a part of water treatment Plant 2. The sludge from both water softening plants is now handled in the same recovery system.

A literature search revealed that practically all investigators had used a vacuum filter for dewatering of the sludge. Believing that centrifugal methods might prove more successful, pilot tests were made on such methods on the sludge from Plant 1. It was discovered by tests that a continuous centrifuge would not only dewater the sludge but would also effect a classification of the sludge, acting to deflocculate the mass, increasing the calcium carbonate component and separating

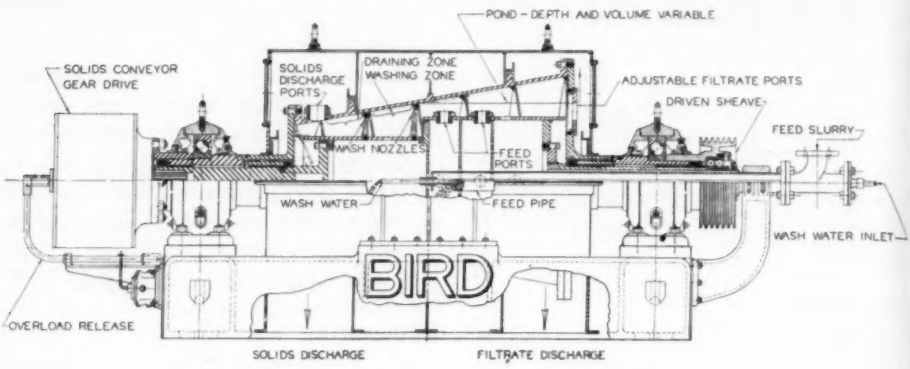

FIG. 8. Cross-section of Bird Centrifuge.

the calcium carbonate from all other impurities, including the magnesium, iron and aluminum compounds, silica and organic matter. It was later learned that there were two installations employing centrifugal methods for sludge dewatering, and at one of these, pilot plant tests were being started on calcination of the resulting sludge cake.

The tests were conducted on a Bird continuous centrifuge, a cross-section of which is shown in Fig. 8. The feed of sludge slurry in controlled volume to the centrifuge is continuous. Entrance is through a stationary feed pipe, feeding into the revolving bowl which is in the shape of a truncated cone. A screw conveyor rotates inside the bowl at a slightly lower speed in the same direction of rotation, and this differential speed between the conveyor and the bowl is obtained by a special gear mounted on the end of the shaft. The centrifugal force developed is up to 1,000 times gravity. The solids are moved forward by the conveyor at a constant rate as fast as deposited and are carried above the level of the liquid for an interval before leaving the bowl. Discharge ports are located at the large end of the bowl, adjustable in depth to maintain the level of liquid take-off at the desired height and the discharge of both solids and liquid is continuous. It is also possible to wash the cake by means of a wash-water inlet if desired. The wash passes through the cake and toward the large end of the bowl with the liquid and the operation requires no cloths, screens or other filter media.

The centrifuge is available in five sizes, varying from an 18-in. diameter unit with a capacity of 1,200 to 1,500 lb. per hr. of dry solids in sludge to a 54-in. diameter unit with a capacity of 40,000 lb. of sludge, based on dry solids per hour. The unit selected for installation at the Wright Aeronautical plant was a 36-in. diameter by 50-in. length bowl with a capacity of 4,000 to 6,000 lb. per hr. of dry solids.

Having determined that it was possible economically to solve the problem of purification of the water softening sludge, it was then necessary to decide whether the plant should be installed to recover calcium carbonate as such or to take the purified calcium carbonate, burn it to lime and re-use it in the water softening process. A preliminary investigation of the local calcium carbonate market indicated that a finely

divided calcium carbonate could be sold locally for soil sweetening, or as a filler in the manufacture of roofing material, plastics, rubber, paint, mill board, etc. These investigations indicated that calcium carbonate could be sold for from $5.00 to $8.00 per ton, providing a product with satisfactory particle size could be assured. Lime is purchased and delivered to the plant at $8.60 per ton.

Table 2 gives the basic elements of cost in this particular case for a study of the economics of calcium carbonate production versus lime production. In actual performance, the quantity of fuel oil required per ton of calcium carbonate has varied from 10 to 13 gal. The fuel oil required for lime production is based on an estimated 12,000,000 Btu. required per ton of lime and with fuel oil at 150,000 Btu. per gal. Labor costs are admittedly high, inasmuch as this is a war plant, and undoubtedly could be materially reduced on normal peacetime operation. The labor for calcium carbonate includes packaging the calcium carbonate ready for market. This comparison indicates a net credit of calcium carbonate production over lime production of $16.40 per day when operating at capacity. The capital investment required for calcium carbonate production is about two-thirds that required for lime burning and, since this is a wartime industrial plant and it was believed that the anticipated market for calcium carbonate was being conservatively figured, the decision was made to proceed with the installation of the calcium carbonate

TABLE 2

Economics of Calcium Carbonate vs. Lime Recovery
Wright Aeronautical Corp.

1. Lime purchased at $8.60 per ton + unload cost $0.40 per ton = $9.00 per ton in bins. Excess lime sold at $5.00 per ton
2. Calcium carbonate sold @ $5.00 per ton

3. *Cost of Production*	*Calcium Carbonate* *Unit*	*Cost per ton*	*Lime* *Unit*	*Cost per ton*
Fuel oil @ $0.035/gal.	12 gal.	$0.42	80 gal.	$2.80
Power @ $0.01/kwhr.	25 kwhr.	0.25	50 kwhr.	0.50
Labor @ $1.50/hr.	0.67 hr.	1.00	1.2 hr.	1.80
Fixed charges		0.70		1.00
Paper bags		1.20		
Total cost		$3.57		$6.10

4. Tons production per day at rated capacity
   - Calcium carbonate 47.8
   - Lime 27.4
5. Total cost per day of product
   - Calcium carbonate $171.00
   - Lime 167.00
6. Total value of product
   - Calcium carbonate 47.8 tons @ $5/ton $239.00
   - Lime 20.4 tons @ $9/ton $183.60
   - 7 tons @ $5/ton 35.00
   - $218.60
7. Net credit from operation per day
   - Calcium carbonate $68.00
   - Lime 51.60

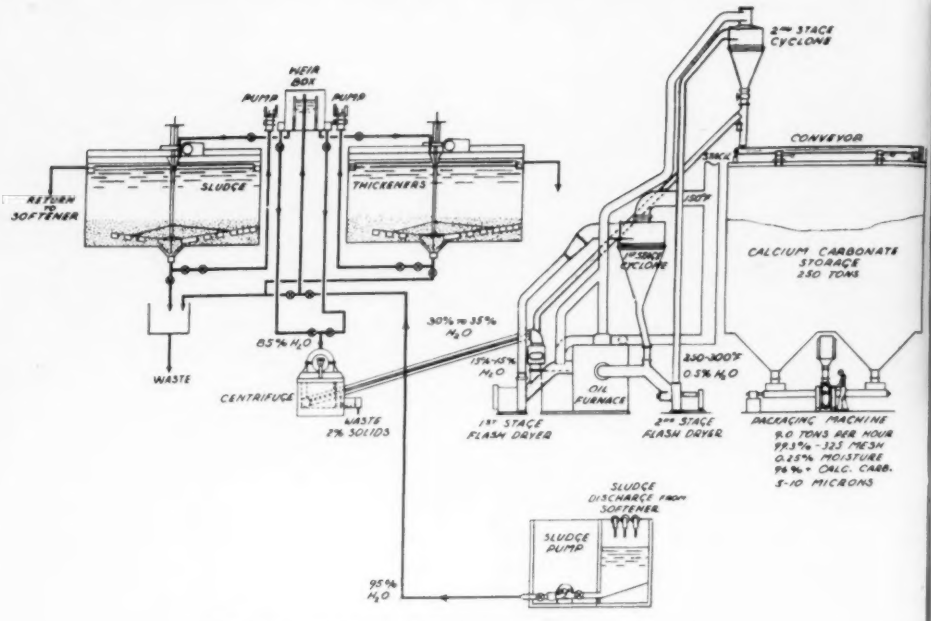

FIG. 9. Calcium Carbonate Drying Equipment.
Wright Aeronautical Corp., Cincinnati, Ohio.

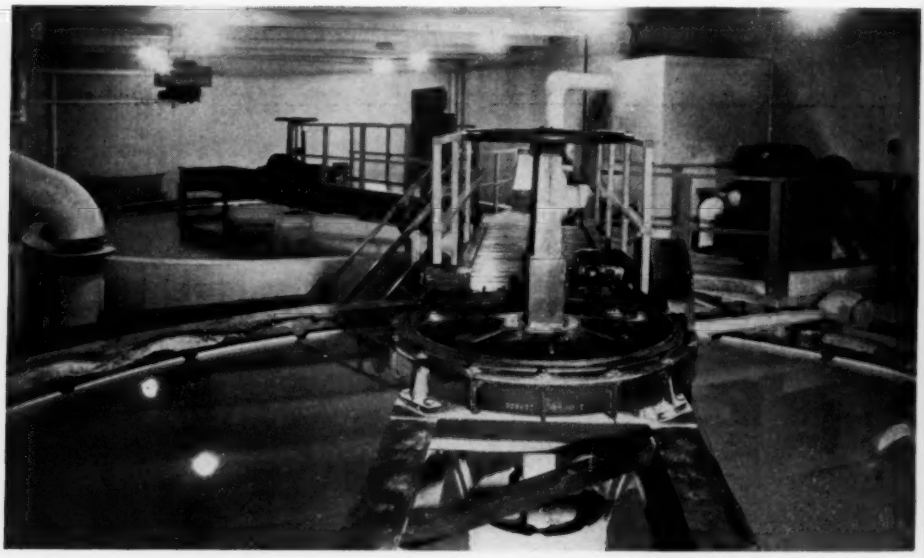

FIG. 10. Calcium Carbonate Sludge Thickeners and Weir Box.
Wright Aeronautical Corp., Cincinnati, Ohio.

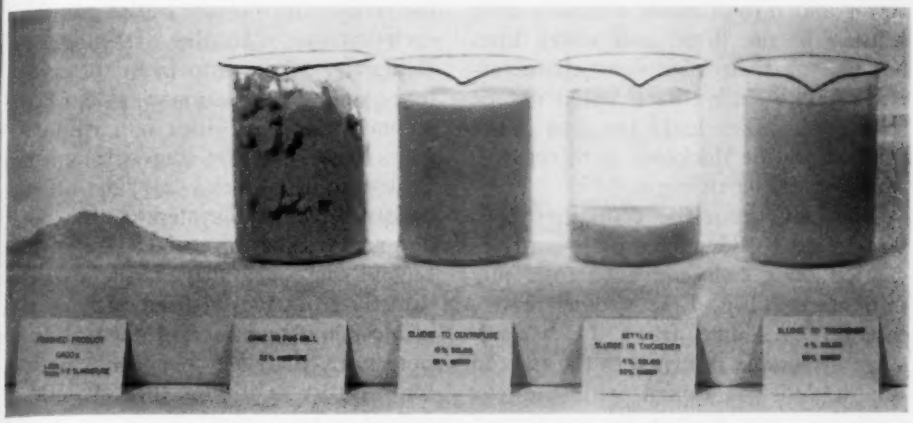

FIG. 11. Samples of Sludge With Varying Moisture Content Taken at Different Points in System.

system rather than the lime recovery system. It should be emphasized, however, that this decision is peculiar to this individual plant, considering tonnage produced, calcium carbonate market, lime cost, equipment cost, fuel and labor. The decision in any specific case as to whether facilities for calcium carbonate recovery or for lime recovery should be installed will resolve into an individual study of the economics of the individual plant.

Calcium Carbonate Recovery Plant Design

The general system is illustrated in Fig. 9. Sludge discharge from the softener contains approximately 5 per cent solids and is pumped by centrifugal sludge pumps to a weir box to distribute the flow to the two thickeners, each 26 ft. in diameter and 12 ft. deep (Fig. 10). The overflow from the thickeners returns directly to the water softener and is recovered at that point. From the bottom of the thickener, settled sludge is withdrawn by means of a sludge pump and discharged to an open box. A constant head on the line to the centrifuge is maintained. Any excess sludge at this point is returned to the thickener. If the centrifuge is stopped, the sludge pump may act to recirculate the sludge. Thickened sludge normally has a moisture content of 85 per cent. Assuming an average ~~moisture~~ solids of sludge in the thickeners of 10 per cent, there is storage room in the two units for 37 tons of calcium carbonate. In these thickeners, there are 22 sq.ft. of area per ton of solids per day. The differences in the characteristics of the sludge water mixture are shown in Fig. 11.

Size of thickeners should be determined by the quantity of sludge to be handled per day as well as by the amount of storage capacity desired. The area per ton of solids per day must be individually determined on each installation, as a number of variables will cause a large difference in the size of thickeners that should be installed.

From the thickener the sludge is fed to the Bird centrifuge and this unit effects the classification and separation of calcium carbonate from other components as previously described. The reject liquors are discharged to the

sewer and do not cause difficulty with settling in the drain and sewer lines because of their flocculent characteristics. The sludge itself could not be so handled. Ten to 15 per cent of the solids from the thickener is rejected to waste by the centrifuge.

The cake from the centrifuge containing 30 to 35 per cent moisture is carried on a belt conveyor to a pug mill mixer (Fig. 12). Sufficient dry calcium carbonate from the second-stage cyclone is returned to the inlet of this mixer and mixed with the wet cake to form a granular mass and eliminate the sticky characteristics, reducing the moisture to from 13 to 15 per cent. The pug mill discharges this mass to the suction of a high-speed fan known as the first-stage flash drier. The first-stage fan takes gases from a discharge of the second-stage cyclone and mixes the mass with these gases feeding to the first-stage cyclone. The operation is controlled by regulating the temperature of the outlet gas from each cyclone. In the first-stage cyclone, the solids drop from the carrying gas into the suction side of the second-stage flash drier fan, while the gases from the first-stage cyclone are vented to the stack, carrying off the moisture from the system at that point and at a temperature of 150° F. The second-stage flash drier fan takes gases directly from the oil-fired furnace and reduces the moisture of the solids to not more than 0.5 per cent, with a temperature in the mixture of 250° to 300°F. The actual moisture in the finished product averages 0.25 per cent. The solids separate from the gases in the second-stage cyclone and are discharged through a rotary valve, where a dry divider regulates the amount of dried calcium carbonate returned to the pug mill and the amount discharged to the screw conveyor, which in turn dumps to the storage bunkers. The percentage of dry cal-

FIG. 12. Calcium Carbonate Cake Discharge From Bird Centrifuge.

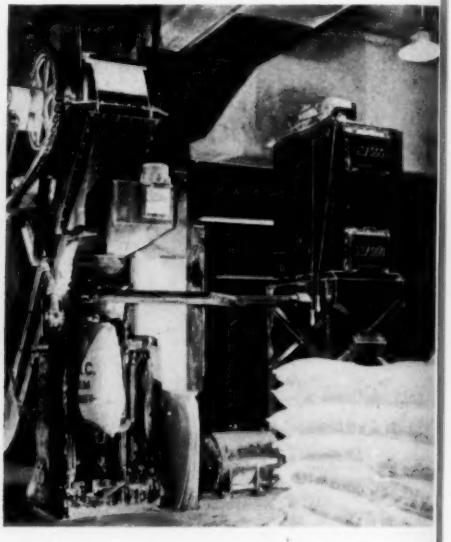

FIG. 13. Calcium Carbonate Packaging Equipment

cium carbonate return may be varied by the operator on a timer from the operating floor. Seventy to 90 per cent is commonly returned to the pug mill.

The furnace is oil-fired and equipped with safety interlocks to prevent damage to the unit. Products of combustion pass to the stage driers, primarily to the second-stage drier, as required to maintain desired temperature. Any excess gas can be passed directly to the stack.

Both of the driers, in addition to handling the calcium carbonate and gases, use the large blades to break up any particle size of agglomerated material. The flow of gases is countercurrent. The amount of calcium carbonate dust discharged to the atmosphere is negligible inasmuch as the vent is from the first-stage cyclone and the solids in that system are still sufficiently wet to obtain a sharp separation of solids from vapor. The calcium carbonate is removed from the bin through rotary locks to a screw conveyor, discharging either to the packaging machine or to the pneumatic system for bulk loading of cars. The packaging machine has a capacity of 9 tons per hr. (Fig. 13). Design data for the recovery system are shown in Table 3.

TABLE 3

Design Data

Sludge and Calcium Carbonate Recovery System

Sludge thickeners, two	26-ft. diam. × 12 ft. deep
Total capacity	300 gpm.
Storage capacity in thickeners, calcium carbonate sludge at 10% average solids	37 tons
Bird centrifuge	36-in. diam. × 50 in. long
Specified capacity	6000 lb./hr. dry solids at 15% solids feed
Raymond flash drying system, capacity	4165 lb./hr. dry solids, evaporating up to 2780 lb./hr. water

MOISTURE CONTENT IN THE SYSTEM

Sludge from softeners	95%
Thickened sludge to centrifuge	85%
Sludge cake, centrifuge to drier	30 to 35%
Pug mill	13 to 15%
First-stage flash drier	6 to 8%
Second-stage flash drier	0.5%
Final dry calcium carbonate	0.25%
Capacity calcium carbonate packaging machine	9 tons/hr.

Performance of Calcium Carbonate Recovery System

Bird Centrifuge

Table 4 illustrates results of analyses on three sets of samples taken at the Wright Aeronautical Corp. and two sets taken from the plant of Columbia Steel Corp. at Provo, Utah. In each case, there are shown analyses of the sludge from the thickener to the centrifuge, of the sludge cake and of the reject from the centrifuge. The improvement of calcium carbonate quality is clearly indicated. The calcium carbonate content in the raw sludge varies from 81.5 to 91.1 per cent and the centrifuge cake varies from 93.8 to 97 per cent. Runs 1 and 2 were on sludge obtained from softening the well waters on the property—waters fairly high in iron. An excellent reduction in the iron content was obtained in the centrifuge on both of these runs. All impurities in the sludge have been reduced in concentration with a resulting increase in the calcium carbonate component. Run 3 was on sludge result-

ing from softening waters from the Miami Valley wells. Because this sludge is quite low in iron content, it produces a whiter calcium carbonate than was possible with sludge from Runs 1 and 2. With this sludge, some silica was found present and it will be noted that the centrifuge has likewise rejected silica as an impurity. The two runs on the samples from Columbia Steel Corp. are on sludge from a surface water supply containing certain amounts of organic matter. The organic matter is considerably reduced by the centrifuge and the classification for magnesium reduction shows results superior to those obtained at Wright Aeronautical Corp. with only 0.1 per cent magnesium as MgO remaining in the sludge cake.

Shown in Table 4 are the percentages of calcium oxide that would result from calcination of either the sludge as fed to the centrifuge, which would be equivalent to the type of sludge obtained on a vacuum filter, or calcination of the sludge from the centrifuge. In each case, the calcium oxide content is sufficiently increased by the classification action of the centrifuge to insure a high-grade lime.

Flash Drying System

A detailed log of operations is kept by the operating personnel on the flash drying system and Table 5 is a summary of the operations for the month of February 1944. This month will prove one of the lightest of the year for actual sludge production because low quantities of water were required by the plant. Peaks were reached during the summer months.

The solids rejected by the centrifuge were 10.3 per cent of the solids fed to the units. The average oil consumption was equivalent to 10.4 gal. per ton of dry calcium carbonate, and with the sludge cake having an average moisture content of 37.5 per cent, an overall efficiency of 78 per cent was indicated for the drying system. From the percentage of calcium carbonate shown on Run 3 in Table 4, it is shown that

TABLE 4

Analyses of Sludges Illustrating Purification by Centrifuge—Percentages

	Wright Aeronautical Corp.									Columbia Steel Corp.					
	Run 1			Run 2			Run 3			Run 1			Run 2		
	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C
Moisture	85.4	33.0	96.4	79.2	33.5	94.8	81.5	29.2	98.9	89.8	39.5	99.0	89.8	39.3	98.2
Solids on Dry Basis															
Calcium as CaO	47.5	54.2	23.5	49.3	53.8	20.6	50.0	52.5	35.0	48.6	50.8	23.7	48.6	51.4	34.3
Magnesium as MgO	1.92	1.32	8.0	2.25	1.7	10.2	3.1	1.48	7.4	2.9	0.1	18.4	2.9	0.1	8.6
Carbonate as CO_2	39.1	42.6	18.5	40.2	42.9	17.4	40.3	41.4	27.6	40.0	42.3	19.9	40.0	42.4	27.6
Iron as Fe_2O_3	0.85	0.49	3.3	2.7	0.4	7.3	0.083	0.046	0.51	0.09	0.05	0.6	0.09	0.05	0.36
Aluminum as Al_2O_3	8.0	1.8	18.6	1.7	0.9	16.2	1.48	0.01	14.1	1.23	0.67	9.4	1.23	0.85	7.6
Silica as SiO_2	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.1	1.3	3.0	3.0	10.0	3.0	—	—
Loss on ignition, not carbonate										3.16	2.17	17.2	3.16	—	—
Probable $CaCO_3$	85.0	96.8	42.0	88.1	96.2	36.8	90.0	93.8	62.5	86.8	90.8	42.4	86.8	91.8	61.2
Possible calcium oxide as CaO in burned lime	81.5	93.8		88.0	94.8		91.1	97.0		87.0	93.2		87.0	92.8	

A = Feed to centrifuge from sludge thickener.
B = Cake from centrifuge.
C = Reject from centrifuge.

in the centrifuge 93.8 per cent of the calcium carbonate has been recovered. The remaining 7.2 per cent is discharged with the impurities.

Quality of Calcium Carbonate Produced

There are several possible variables in the operation of the Bird centrifuge that will affect the degree of purification of the calcium carbonate. Speed may be varied to give centrifugal force up to 1,000 times gravity by the use of different sheaves. The setting for the discharge ports for the reject liquids can be varied. The consistency of solids fed to the centrifuge is an additional variable and the washing of the cake still another. As the analysis will indicate, it is possible to produce readily a calcium carbonate with a $CaCO_3$ purity of 93 to 97 per cent.

While these runs are on sludges from water softening plants employing selective calcium softening, precipitating relatively little magnesium, there is no doubt that practically complete magnesium elimination from any water softening sludge can be obtained by this method where magnesium and other impurities are present in amounts up to 40 to 50 per cent of the total of the sludge solids. In each case it is merely a question of proper adjustment and operation of the centrifuge to obtain the separation desired, irrespective of the relative percentages of the components. Calcination of the sludge cake will therefore not result in any accumulation of impurities or degradation of the quality of the resulting lime, inasmuch as the impurities are rejected on each cycle through the centrifuge, and a consistently high quality of lime from the calcination of the sludge cake is assured.

TABLE 5

Performance of Flash Drier in February 1944

Total hours operated (in 27 days)	189
Average solids (dry basis) from thickener, *lb./hr.*	5065
Average moisture, thickener solids, %	15.8
Fed to centrifuge, *gpm.*	57.9
Average solids (dry basis) reject from centrifuge, *lb./hr.*	520
Average solids reject, %	10.3
Average solids (dry basis) to flash drier, *lb./hr.*	4545
Total calcium carbonate produced for month, *tons*	438
Average calcium carbonate per day, *tons*	16.2
Average $CaCO_3$ in feed to centrifuge @ 90%, *lb./hr.*	4550
Average $CaCO_3$ in recovered dry product @ 93.8%, *lb./hr.*	4260
Average $CaCO_3$ lost in reject, *lb./hr.*	290
$CaCO_3$ in reject solids, calculated, %	56.0
$CaCO_3$ in reject solids, analysis, %	62.5
Efficiency of $CaCO_3$ recovery, %	92.6

Examination of the dried calcium carbonate has indicated an average particle size of 5 to 7 microns. A screen analysis of the product indicates 96 + per cent through a 325-mesh screen. The oversize consists primarily of sand and grit brought into the plant with lime and its presence has affected the marketability of the calcium carbonate for certain uses where it otherwise could bring a higher price. Pilot plant tests have been completed, and there has been installed a vibrating screen to wet-screen the sludge at a point between the discharge from the thickener and the Bird centrifuge; in other words, to screen the sludge with the moisture content of 85 per cent. A single 3 × 5-ft. screen with a 200-mesh screen cloth working on an angle will adequately handle the production at this plant. The oversize removed from the screen will be taken at 60 to 65 per cent moisture and can be removed from the plant as grits. The

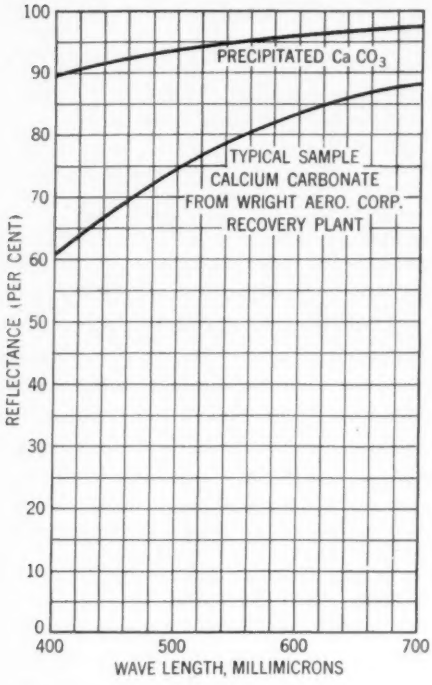

FIG. 14. Color of Calcium Carbonate Produced Compared with Color of Precipitated Calcium Carbonate.

pilot plant tests show that the use of the screen will result in 99.4 to 99.5 per cent being retained by the 400 mesh, with a maximum of only 0.2 per cent being retained on 325 mesh. With this improvement in particle size, no difficulty is anticipated in marketing the calcium carbonate at a higher price than that now obtained, probably ranging from $6.00 to $9.00 per ton.

Tests have been made on the color of the calcium carbonate and Fig. 14 shows a comparison of a precipitated commercial product with the dry calcium carbonate obtained at the time of Runs 1 and 2 and illustrated in Table 4. Brightness of the color is appreciably below that of the commercial product, but the difference is due primarily to the relatively high iron content of 0.4 per cent. The calcium carbonate obtained in Run 3 has only 0.046 per cent iron and tests will undoubtedly indictate a better comparison with a precipitated commercial product. The brighter material is now consistently available from the water with a lower iron content. It is believed that it is also possible to lower further the iron content in the cake by more careful adjustment of the classification in the centrifuge.

Columbia Steel Corp., Provo, Utah

When it was decided to locate a large steel mill in the Salt Lake Valley for production of steel for use on the West Coast, the problem of water supply for this mill received careful study by the responsible engineers. Fresh water is a scarce commodity in the valley and its use is carefully rationed by means of water rights. The raw water supply selected for the mill was from Deer Creek Reservoir on the Provo River. The average demand was estimated at 8 mgd. with a peak demand of 12 mgd. Because of the use of the water in many critical operations involving heat exchange and because of the mineral content, it was decided to employ selective calcium softening for reduction of the calcium hardness.

Reference to Table 6 will indicate the characteristics of the raw and treated waters obtained by selective calcium softening at the Wright Aeronautical plant and the Columbia Steel plant. The calcium hardness has been reduced to a minimum practical level by the cold process softening, with relatively little reduction in magnesium hardness. By proper pH control, the reduction in magnesium hardness has been held to about 8 per cent on the plant well water and is nil on the

Miami Valley well water at the Wright Aeronautical Corp. On the Provo River, at Columbia Steel, the reduction in magnesium hardness is 18 per cent. The pH value has been reduced in each case sufficiently to yield a stabilized water.

A flow sheet of the treatment plant is illustrated in Fig. 15. The reservoir is located in the mountains several miles from the plant and the water is pumped over and down the mountains to the plant. The treatment plant is designed for constant-rate operation, because the effluent from the treatment plant is used as make-up water for an 800-mil.gal. reservoir. An average of 122 mgd. is circulated from the reservoir through the steel mill and returned, minus certain losses, to the reservoir. The losses vary with the surface evaporation, which varies with the degree of cooling of the water. The portion of the water required for make-up to the evaporators at the boiler house and for use in the waste heat boilers is filtered as well as softened. The water passing directly back to the reservoir is softened and recarbonated only. Two softening basins are installed, each with a capacity of 6 mgd. These basins are of the upflow type with a circulating slurry pool and the two basins, each 54 ft. in diameter, have operated steadily on a 12-mgd. load and consistently delivered a softened effluent water with a turbidity averaging 3 ppm.

While there is an appreciable amount of ground available where sludge from

TABLE 6

Characteristics of Raw and Treated Water

	Wright Aeronautical Corp.				Columbia Steel Corp.	
	Plant Wells		Miami Valley Wells		Provo River	
	Raw	Treated	Raw	Treated	Raw	Treated
Total hardness, $CaCO_3$—*ppm*	521	201	305	139	256	90
Calcium hardness, $CaCO_3$—*ppm*	349	43	203	40	180	38
Magnesium hardness, $CaCO_3$—*ppm*	172	158	101	99	76	52
Free carbon dioxide, CO_2—*ppm*	28	0	35	0	2	0
Total alkalinity, $CaCO_3$—*ppm*	331	71	280	69	196	72
pH	7.2	8.6	7.3	8.7	8.2	8.1
Chemical Requirements						
Lime, *lb./mil.gal.*	2120		1860		1140	
Soda ash, *lb./mil.gal.*	530		0		260	
Alum, *lb./mil.gal.*	170		170		150	
Calcium carbonate precipitated, *lb./mil.gal.*	5950		4350		3000	
Plant capacity, *mgd.*	8		22		12	
$CaCO_3$ per day at rated capacity, *tons*	23.8		47.8		18	
Possible lime recovery, 92% $CaCO_3$ recovered, tons per day, as 90% CaO			27.4		10.3	
Lime required for water softening, tons per day, as 90% CaO			20.4		7.6	

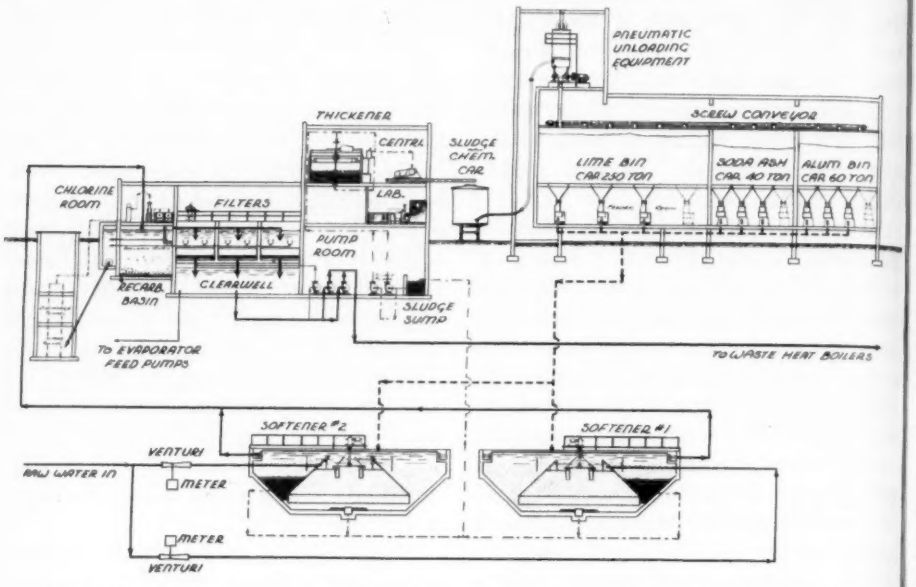

FIG. 15. Architectural Flow Sheet—Water Softening Plant—12-mgd. Capacity. Columbia Steel Corp., Provo, Utah.

this plant could be ponded or lagooned, plans were made to install, with the plant as first designed, sludge dewatering equipment employing the classification principle of the centrifuge. The purpose was to check its operation on this surface water supply, and if proven satisfactory, to proceed later with the installation of a lime burning plant.

The water treatment plant is in operation at a rated capacity of 12 mgd. and has been producing a dewatered sludge cake that at the present time is being hauled away to dump by sludge cars. Tests on the centrifuge, as indicated by means of Runs 1 and 2, Table 4, illustrate the high degree of purification of sludge obtained. The data in Table 7 summarize the economics of lime recovery for the plant, together with a calculation of the amount of heat required for an efficient lime burning system. At this plant, the circumstances influencing the choice between recovery of calcium carbonate or reburning to lime are entirely different from those at the Wright Aeronautical plant. Fuel is relatively inexpensive and coke gas as a byproduct is available. Power and labor are both relatively less expensive, and it is estimated that a lime burning plant to handle this capacity can be installed for approximately $55,000. It may be noted in Table 6 that 7.6 tons of lime per day are required for water softening, while 10.3 tons per day can be recovered from the sludge. This additional production is worth as much per ton to the steel company as the lime used for water softening, as there are a number of other points in the mill where lime is required in sufficient amounts to consume the excess. Another favorable factor is the high cost of lime at $16.00 per ton in box carload delivered to the plant. The eco-

nomics (Table 7) of this study indicate that, taking into consideration the cost of disposal of the present sludge, a lime burning plant will pay for itself in one year's time. With no local markets of any appreciable size for a dried calcium carbonate, there is no question that, at this location, lime recovery is indicated. The use of reburned lime will also eliminate the problem of excessive grits in the lime slaker, resulting from the impurities in the present inferior lime supply.

TABLE 7

Economics of Lime Recovery
Columbia Steel Corp., Provo, Utah

Estimate of Heat Requirement for Calcination	*Btu. per ton lime*
Evaporation of water, 40% from sludge cake, 2280 lb. H_2O/ton CaO×1100 Btu./lb.	2,500,000
Calcination, 1250 Btu./lb. CaO from $CaCO_3$	2,500,000
Sensible heat of lime, 500 Btu./lb. CaO	1,000,000
Allowance for losses, radiation, etc.	2,000,000
Total	8,000,000

Estimate of Operating Costs for Calcination	*Cost per ton*
Fuel, coke oven gas, 8,000,000 Btu./ton, @ 11¢/1,000,000 Btu.	0.88
Power, 50 kwhr./ton @ 0.5¢/kwhr.	0.25
Labor, 1.25 hr. @ 1.20/hr.	1.50
Fixed plant charges, @ 10% per annum	1.53
Total cost per ton	$4.16
Present cost per ton @ $16.00 + unload cost $0.40	$16.40
Net savings per ton of lime	$12.24
Net savings per day on capacity production @ 10.3 tons/day	$126.00

Types of Calcination Systems

There are two types of units now on the market that can be adapted to purify water softening sludges—the wedge furnace and the rotary kiln. The wedge furnace is adaptable for handling small quantities of material but has the disadvantage of a considerable weight to be supported on a relatively small area. Maintenance of the rabble arms on several installations is reported to be relatively high, with frequent replacements necessary because of the temperatures maintained. Capacities as low as a few tons per day, however, can be handled in this type of unit. Rotary kilns will undoubtedly prove more adaptable for larger tonnages—from 10 tons of lime per day up (Fig. 16). Dust collectors should be provided and the kiln must be specially designed to handle the powdered product, preferably incorporating chain systems at the inlet. The rotary unit must be relatively long to insure complete calcination and temperatures must be properly controlled to avoid over-heating of refractory linings. It is understood that there is under development a third type of unit employing flash calcination. It is a modification in the design of the Raymond flash drier described by Pedersen [see page 1170 of this JOURNAL].

Now that the problem of purification of water softening sludges has been solved by an economical process, a calcination unit for handling of small quantities of sludge, as well as of larger quantities, is definitely needed for use in this field. It is hoped that flash calcination or similar methods can be successfully developed to make the economics and possibilities of lime recovery available to small water treatment plants as well as to larger installations. Recovery of carbon dioxide from such calcination processes would prove useful to larger installations for produc-

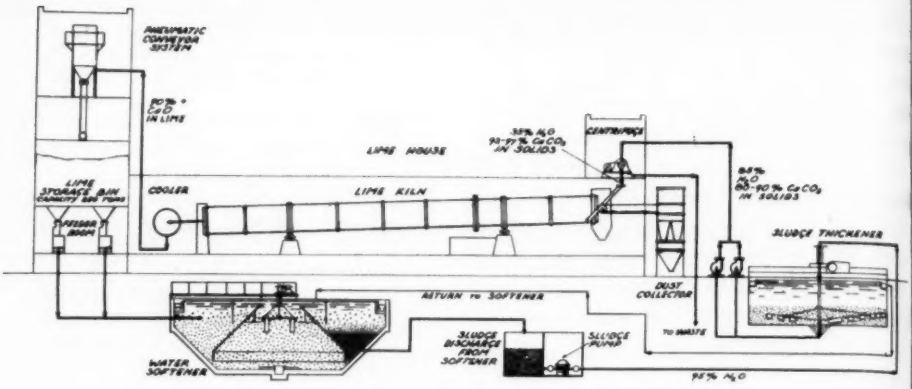

FIG. 16. Typical Flow Sheet of Recovery of Lime From Sludge. Columbia Steel Corp., Provo, Utah.

tion of "dry ice" or other industrial applications, or for recarbonation of the water in the treatment process.

In considering the size of the installation, it must be understood that the volume of water treated affects the size insofar as the recovery from sludge is concerned only to the extent of the amount of sludge produced. In other words, 10 tons of calcium carbonate per day may be produced from a 2-mgd. plant or a 12-mgd. plant, and yet the economics of recovery from sludge will be practically the same for both plants, assuming, of course, equivalent conditions on other variables. While it is difficult to define the point at which recovery of sludge may prove attractive, inasmuch as some study of the economics would be required in each case, it is probable that the "break-even point" is in the neighborhood of 5 to 10 tons of sludge per day. The adoption of systems for recovery from sludge of calcium carbonate or lime, and possibly carbon dioxide, will answer the long-felt desire to do something about the waste product which is dumped from a water treatment plant, adding to the solids content of the receiving stream. At the same time to recover valuable products will make the process well worth while.

Acknowledgments

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British Waterworks Association Committee on Reclamation of Water Softening Sludge

The British Waterworks Association has formed a committee to investigate recovery of lime from sludge. The procedure that has been planned is "to invite tenders for lime reclamation plants specially designed to treat softening sludge and to select one or more suitable types of the smallest practical size and try these out under working conditions."

The B.W.A. judges that, "for the plant to be efficient, it must produce lime without creating a dust nuisance, and at an overall cost which will compare favorably with the prevailing market price of lime."

In the circular which went out to the B.W.A. membership, announcing the formation of the committee, it was suggested that "Water undertakers interested should join together in financing the experimental work necessary. The committee . . . will carry out preliminary investigations and prepare a report on the cost of testing an experimental plant under working conditions."

Calcining Sludge From a Softening Plant

By H. V. Pedersen

WHEN the management of the water works at Marshalltown, Iowa, decided in 1937 to soften the city water supply, it did so knowing the available space in which to waste the sludge was limited to three or four years' operation. Therefore it immediately began looking for a permanent solution to the sludge disposal problem. Among the possible methods which presented themselves at that time were: dewatering or thorough drying of the sludge and selling of it as a calcium carbonate; and calcining or conversion of the calcium carbonate in the sludge to calcium oxide so that it could be used in the process of softening.

In order to obtain helpful information a search was made for data on calcining and for anyone experienced in the use of recalcined lime. Very little data of value which could be applied directly to the problem were disclosed, so it was decided to install a dewatering or drying plant and make an effort to develop a market for the calcium carbonate. The drying plant, which was built in 1941 as a result of this decision, proved to be very satisfactory but the result of an effort to sell the carbonate did not come up to expectations. The carbonate accumulated so rapidly and the sales were so slow that it became just as much of a problem to dispose of the dried sludge as it was to find a place for the wet sludge. It was resolved to go a step further and find out by experiments, if possible, whether it would be practical to calcine the dried sludge produced in the drying plant.

Calcining, in one sense of the word, may be a comparatively simple process, for men have known for centuries that if calcium carbonate in the form of limestone is heated above 1800°F. carbon dioxide is liberated, leaving a quicklime. But it did not take long to discover that it might not be easy to calcine dried sludge from the softening plant because of the great amount of impurities and the peculiar characteristics of the dried material.

Thoroughly dried solid residue recovered from water softening plant sludge is probably one of the smallest grained materials in existence. An accurate analysis of the dried sludge at Marshalltown by the Oden sedimentation method disclosed that 99.8 per cent passed a 325-mesh screen while 20 per cent passed a 3,000-mesh screen. When some of this dried material, at room temperature, is placed in a container it tends to compact firmly when the container is tapped gently and will readily arch. When heated to 350°F. this material seems to expand and flows like quicksilver when spilled on

A paper presented on June 14, 1944, at the Milwaukee Conference, by H. V. Pedersen, Supt. and Gen. Mgr., Marshalltown Water Works, Marshalltown, Iowa.

the floor and it is almost impossible to sweep it up until it has cooled. When it is heated to a temperature of 1800°F. it takes on new characteristics, for it tends to stick or adhere to any surface with which it comes in contact. No attempt has been made to compare these characteristics with those of other sludges and it may be that they would differ from one another according to the kind of water softened. There may be an explanation for the tendency of the hot sludge to adhere to any surface. It is suspected that it may be due to the iron content.

Although heat is essential, it is not necessarily the controlling factor in calcining dried sludge from a softening plant. If a large open-top receptacle is filled with dried sludge and heated until the entire mass reaches a temperature of 2000°F., it will be found by laboratory tests after cooling that very little carbon dioxide has been liberated. The material is so fine in texture that carbon dioxide simply cannot escape through the voids as long as it remains motionless, but if the material in the receptacle is stirred vigorously while still hot much better results are obtained. However, if dried sludge is sprayed directly into a flame as a mist, carbon dioxide is liberated instantaneously and calcination is complete.

To determine how to build a furnace best suited for calcining dried sludge from a softening plant, the trial and error method was followed. A furnace was constructed out-of-doors using cheap common brick, several thousand firebrick and an oil burner having a full requirement of 7 gal. per hr. Because of a complete lack of knowledge and the possession of only a few vague ideas on the part of the builders, the first furnace consisted of a horizontal, rectangular combustion chamber, 15 in. square and 5 ft. long, and a settling chamber, 2 ft. wide, 4 ft. high and 10 ft. long. All of the brick was laid with a very poor grade of mortar so the furnace could be torn apart quickly and easily without damaging the brick. After this first furnace was operated for several days and results observed it was torn down and a second one built. When all the results from the second furnace were obtained, it too was torn down and a third one built. The furnace was torn down and rebuilt eight times and each time the size and shape of both the combustion and the settling chamber were changed or modified. When some particular feature looked promising in one furnace it would be accentuated in the next. Horizontal and vertical, round-the-end, and up-and-down baffles were tried in both horizontal and vertical settling chambers to determine which were most effective. One combustion chamber was increased in length and another was decreased, while still another was shaped like a cylinder. The idea of constricting certain sections of the combustion chamber which at first looked promising was also thoroughly tried, and so it went until each and every idea conceived was incorporated and tried long enough to observe results.

The first attempt to break up the dried sludge and satisfy the first basic requirement consisted of injecting the material into the flame of a furnace by means of air. This method broke up the material readily enough but the quicklime produced was discolored with soot as a result of imperfect combustion. Then a series of experiments was conducted to determine how and at what point the material could be injected advantageously without up-

setting combustion. Injection pipes were inserted at 1-ft. intervals along one side and top of the combustion chamber at various angles but none of the results were satisfactory, for no matter where the point of injection was placed the air used upset combustion just enough to spoil the quicklime for further use.

One other method used consisted of dropping dried sludge into a horizontal flame at a point where the walls of the combustion chamber had been constricted. This seemed promising at first because the slightly increased velocity broke up the material fairly well and carried it to the settling chamber. But just as soon as the combustion chamber became thoroughly hot the material adhered to the walls and built up to such an extent that it shut off the draft completely.

After several more ideas were tried without success, and when it looked as though a stationary type of calcining furnace would not be practical, it was discovered that if dried sludge falls 7 or 8 ft. through a vertical chamber in which splash plates are set at an angle of 60 deg., it is well broken up. The experimental furnace was torn down for the seventh time and rebuilt with this idea incorporated. The combustion chamber of the eighth furnace was built on an angle of 30 deg. with the floor for 6 ft. and then vertical for 8 ft. The feed chamber with the splash plates, which has been named the "gravocity" chamber, was built parallel to the vertical portion of the combustion chamber so the material would splash into the hottest part of the flame. A collecting well was provided below the vertical part of the combustion chamber. A vertical type settling chamber equipped with a collecting well below and vertical baffles was also provided. When this furnace was operated the results were quite gratifying. Practically all of the available calcium carbonate in the dried sludge was calcined and the quicklime came out clear and clean.

Encouraged by these results, a little better insulated calcining furnace equipped with a gravocity splash plate system, was added during the summer of 1943 to the regular drying system which had been installed in 1941. A brief description of this combined drying and calcining system follows: Sludge is drawn from the clarifier of the softening plant and pumped to a storage tank located on the second floor of the building housing the drying equipment. From this tank the sludge is fed by gravity to a Bird centrifuge for dewatering. The cake is then thoroughly dried in a Raymond "flash drying" system and elevated to a cyclone located directly above the furnace. From this cyclone the dried carbonate either drops into a hopper of a horizontal screw-type feed machine which feeds it uniformly into the vertical feed chamber of the furnace or is conveyed to a sacking arrangement where it can be sacked if desired.

The calcining furnace was 6 ft. 7 in. wide, 10 ft. long and 17 ft. high overall. The flame was supplied by three oil burners located at the bottom of one end of the furnace and the temperature at the splash plate was maintained at 2000°F. The heat required for drying was drawn from the opposite end of the furnace from the burners so it might be said that the same heat produced in the calcining process was used to dry the next batch of sludge ready for calcining, although it was a continuous process. The calcium oxide or quicklime produced was removed from two collecting wells at the bottom

of the furnace by means of water-cooled screw type conveyors and conveyed to a sacking device where it was sacked and delivered to the softening plant. The drying part of this system has a capacity of 700 lb. per hr. of dried carbonate and the calcining furnace could handle all the carbonate as fast as it was dried.

All during the experimental and construction period and long before any recalcined lime was produced there was considerable apprehension as to how it would react in the softening plant. Naturally this feeling of doubt was reflected somewhat in constructing the calcining furnace just described. It was evident that if recalcined lime could not be used successfully in the softening plant there was little sense in building an expensive furnace or installing expensive equipment. On the other hand it was certain that if a sufficient quantity of satisfactory recalcined lime could not be produced there would be no way to determine whether or not it could be used. So when the first calcining furnace was designed the chief objectives were to prove that sludge could be calcined and then to demonstrate whether the recalcined lime could be used successfully. Until these interdependent objectives were attained, cost of production, efficient methods and other factors would be more or less secondary.

It was known that the raw water from the wells supplying the city contained 20 ppm. magnesium and 3 ppm. iron. Therefore much doubt had also arisen during the experimental period concerning the number of times the sludge could be recalcined and used in the softening plant as a complete cycle before the percentage of magnesium in the recalcined lime reached an objectionable limit. As there was only one sure way to find out, the complete cycle of operation was put in motion.

As soon as everything was ready, the experimental and more or less temporary calcining furnace was started and operated until 5 tons of recalcined lime were produced. Attention was then turned from calcining to the long-waited-for try-out in the softening plant. In order to hold to a minimum the possibility of upsetting the softening plant, lime was at first fed on a fifty-fifty basis. Then at intervals the rate of feed of one was increased and the other decreased until the ratio of the recalcined lime to commercial lime became 2 to 1, then 3 to 1 and so on until practically the entire load was transferred to the recalcined lime. The results exceeded expectations, for the transition was made without any perceptible change in alkalinity or quality of water. The recalcined lime slaked readily in 120 deg. preheated water maintaining a slaker temperature of 140 deg. The floc in the mixing or reaction chamber was excellent and settling in the clarifier was good. In fact the only criticism that could possibly be made was that a larger quantity of recalcined lime was fed in proportion to regular commercial lime to offset the lower oxide content. But gratifying as these results were it was only a beginning.

After operating in unison for 30 days without interruption, calcining every pound of recovered sludge and using every pound of recalcined lime in the softening process and completing the cycle every four days, the amount of calcium carbonate in the sludge cake did not fall below 88 and the impurities in the recalcined lime did not increase beyond 15 per cent. Table 1 lists results obtained after each

cycle for three complete cycles. After three complete cycles everything leveled off and remained fairly constant.

The water content of the sludge as drawn from the clarifier varied from 87 to 92 per cent; that is, the total solids in the sludge increased from 8 to 13 per cent as the amount of recalcined lime was increased. This of course varied somewhat depending on the schedule of sludge withdrawal. It may be interesting to note here that a comparatively thick sludge is one that produces 1 lb. of dried cake per gal. while a comparatively thin sludge is one which produces only 1 lb. for every 1.6 gal. Under normal drying conditions when only regular commercial lime is used, 80 per cent of the total recoverable solids is actually recovered as a sludge cake by the centrifuge while 20 per cent is washed out with the water in the centrate. When recalcined lime is used in the softening plant the sludge is thicker and the amount of solids recovered by the centrifuge drops at times to as low as 75 per cent of the total, while the amount washed out in the centrate sometimes increases to 25 per cent. The moisture content of the cake as it leaves the centrifuge consistently tests 35 per cent under all conditions. The calcium carbonate in the dried cake varied between 88 and 93 per cent, the magnesium varied between 2.5 and 6 per cent, while the iron varied between 5 to 9.5 per cent. The calcium carbonate in the dried solids washed out in the centrate varied between 20 and 25 per cent, the magnesium varied between 65 and 70 per cent and the iron varied between 8 and 12 per cent. Applying these percentages to the daily total sludge withdrawal it will be seen that between 6 and 7 per cent of the total calcium carbonate is lost, or sacrificed, so to speak, by the centrifuge to get rid of between 80 and 90 per cent of the total magnesium and between 30 and 40 per cent of the iron.

After the calcining furnace had been in operation for several weeks it was noted that the amount of impurities in the recalcined lime did not increase or build up as much as the amount of iron and magnesium in the sludge cake would indicate. This was rather puzzling at first but then it was discovered

TABLE 1

Components	Control			First Cycle			Second Cycle			Third Cycle		
	Straight Commercial Lime			50% Re-calcined Lime, 50% Commercial Lime			60% Re-calcined Lime, 40% Commercial Lime			60% Re-calcined Lime, 40% Commercial Lime		
	80% Solids in Cake 20% Solids in Centrate			10.2% Raw 3.0% Centrate		75% Cake 25% Centrate	11.07% Raw 3.0% Centrate		75% Cake 25% Centrate	13.1% Raw 3.8% Centrate		77% Cake 23% Centrate
	Raw	Cake	Centrate	Raw	Cake	Centrate	Raw	Cake	Centrate	Raw	Cake	Centrate
Fe_2O_3 Present—%	4.76	9.5	9.0	7.02	5.4	11.0	8.2	7.0	11.7	7.6	7.0	9.6
$Mg(OH)_2$ Present—%	16.10	2.5	67.8	22.80	6.0	64.8	20.4	2.5	68.1	18.6	4.9	69.2
$CaCo_3$ Present—%	78.80	88.0	23.2	71.00	93.0	24.2	71.4	90.0	20.2	73.6	88.3	21.2
Fe_2O_3 Removed—%			1.6			44.0			39.0			27.0
$Mg(OH)_2$ Removed—%			87.0			81.0			91.0			80.0
$CaCo_3$ Lost—%			5.7			4.2			7.7			6.6

that the material which fell off each night after the furnace temperature cooled down was practically all iron and magnesium. When this fact was definitely established it was not difficult to see that if this furnace coating could be removed each morning and wasted it might result in a very good iron and magnesium control. Although not all the possibilities have been fully explored, several hundred pounds of iron and magnesium have been removed after a day's run at the expense of a few pounds of calcium oxide.

The stationary flash type calcining furnace described, in which the recalcined lime was produced, worked quite well, but not as well as desired nor as well as it is possible to make a better designed furnace work, for it would have been little short of a miracle if perfection had been attained in the first attempt. Sixty tons of recalcined lime were produced and used during the test run although over a hundred tons were produced during the winter. When feeding calcium carbonate or dried sludge into the flame at the rate of 700 lb. per hr., 350 lb. per hr. of lime averaging 82 per cent calcium oxide was removed from the furnace. The total amount of calcium in the recalcined lime calculated in terms of calcium oxide varied from 85 to 88 per cent. Therefore the 82 per cent actually means that from 93 to 96 per cent of the total available carbonate was converted into oxide.

When the light grayish-colored dried sludge cake or calcium carbonate is fed into the flame of the calcining furnace and the carbon dioxide is expelled, the resultant quicklime immediately takes on new characteristics. Its color not only changes to a light tan but it has a fluffy appearance and the significant thing is that the fluffier it looks the better the quality. Volume for volume, a good grade of recalcined lime weighed 85 per cent of an equal volume of carbonate. Furthermore, the better the grade of lime the less tendency it has to arch and it feeds very well from a hopper to a slaker. It is not a difficult product to handle when one is properly equipped and it does not air slake as rapidly as commercial lime. In the final analysis it is no longer a question of whether recalcined lime is desirable or whether it can be used successfully in a softening plant. It is strictly a problem of perfecting a method of calcining which will produce as good a grade of lime as possible at the least expense.

No attempt has been made here to discuss the question of cost or to debate the relative merits of a stationary flash-type calcining furnace versus a rotary type. It should be stated, however, that either type probably will have certain advantages and disadvantages depending largely on local conditions and that it will be possible in many localities to produce lime from waste sludge of a softening plant at a cost not exceeding the cost of commercial lime. Furthermore, it is certain that no city can continue to postpone the softening of water on the excuse that it cannot dispose of the sludge. Calcining is practical, and it is possible that some day this process will become an integral part of many softening plants.

Calcining Sludge From a Water Softening Plant

By Charles W. Gordon

PEDERSEN and Lammers and Sheen have made a significant contribution to a most pressing problem—the disposition of lime sludge.

The drying and calcining equipment used in the plants under discussion is of the the flash type. The term "flash drying" is the copyrighted trademark for C–E Raymond drying systems. Flash drying is the instantaneous removal of moisture from materials in a turbulent stream of hot air.

The flash drying system used in these plants is the counterflow type, consisting of a wet and a dry stage. This type was selected to give low discharge gas temperatures and a negligible loss of fine material in the vent gases.

The centrifuged cake containing from 35 to 40 per cent moisture is discharged to a mixer where it is conditioned by adding a predetermined amount of previously dried material. The average moisture is reduced to the point where the material becomes quite fluffy.

The conditioned material is discharged to the wet stage. Predrying is accomplished in the wet stage and the gases from this stage only are discharged to the atmosphere. The temperature of these gases is 150° to 160° F. and they carry about 0.1 g. per cu.ft. of calcium carbonate. This vent loss is about 0.2 per cent of the dry solids in the wet cake fed. Thus the wet stage acts as a wet dust collector and no expensive secondary dust collector is required.

The predried material is discharged to the dry or finishing stage where final drying to approximately 0.5 per cent is accomplished.

The wet cake at 35 to 40 per cent moisture is converted to a dry, finely divided powder in about 10 sec. From 80 to 99 per cent will pass through a 325-mesh screen. The source and purity of the original lime will be an important factor in final screen analysis.

The finished product is discharged from the dry stage into a storage bin and then sacked in paper bags for shipment. Calcium carbonate is widely used in industry as a filler for many compounds.

If the calcium carbonate is not to be sold, the next step is calcination for re-use. Pedersen has described the steps in the development of flash calcination in a most interesting manner. The progressive attitude of Pedersen and the Marshalltown Water Board is to be highly commended.

A discussion of papers by Robert T. Sheen and H. B. Lammers and H. V. Pedersen (see page 1145 and page 1170) presented on June 14, 1944, at the Milwaukee Conference by Charles W. Gordon, Raymond Pulveriser Div., Combustion Engineering Co., Inc., Chicago, Ill.

Calcination for re-use is an old art and the development of new equipment is justified only when present equipment is unsuitable. A careful investigation of this field indicated that existing equipment would be unsuitable to water plant operation.

Water plant operating requirements impose several limitations on calcining equipment, the most important of which are:

1. Intermittent operation.
2. Ability to produce calcium carbonate.
3. Freedom from dust nuisance both inside and outside.
4. Maximum thermal efficiency.
5. Minimum building space.
6. Adaptability to a wide range of plant capacities.

The flash calcination system as described by Pedersen meets all the above specifications.

The system may be started after an overnight shut-down in 30 min. It can be stopped in 15 min. without any detrimental effects at the end of the day's run, which may range from 8 to 16 hr. No long and slow heating-up and cooling-off periods are required. No fuel is used between operating periods.

Since there is a good market for calcium carbonate, the system should be able to produce this product as required. The dried carbonate is produced as the first step in the C–E Raymond system and may be withdrawn or calcined as desired.

The system is under suction; hence there can be no dust nuisance inside the building. Previous discussion showed that by test the vent loss was negligible.

The vent temperature from the system is from 150° to 160°F. This approaches the dew point and the vent is almost saturated. This condition gives maximum thermal efficiency. The hot gases used for drying are the spent gases from the calcining furnace.

The flash calcination system is of vertical design and requires a relatively small floor area as compared with horizontal kilns of the same capacity. The height required is also moderate.

This system, by its very nature, is easily adaptable to any size of plant, from the very smallest town to a plant serving a city of millions of people.

Pedersen has indicated that his paper is a progress report. After some refinements, it is planned to operate the calcining equipment as a part of the regular plant routine. At that time some very interesting data will be available on the economics of the process. It is planned to have the final design ready for immediate postwar use.

Recalcination of Water Softening Sludge

By Frederick G. Nelson

THE disposal of sludge from the lime and soda softening process is an engineering problem except at plants where it can be dumped without complaint into large bodies of water. It is of increasing importance, even for cities so located, because state departments of health and the public in general no longer look with favor upon the disposal of lime sludge in this manner. As a result many cities have had to resort to lagooning. However, lagooning is not a satisfactory solution because of its unsightliness and the space required for lagoons.

Help in visualizing the problem may be derived from some figures on the amount of sludge produced when lime is added to water. Theoretically, for each pound of calcium oxide added, 3.5 lb. of calcium carbonate is formed. Actually the ratio of sludge produced to lime added is less than this because of other factors, such as the presence of magnesium and free carbon dioxide and of inert material in the lime. Probably an average figure is about 2½ lb. of sludge, on a dry basis, for each pound of commercial quicklime added.

To illustrate, let it be assumed that a water requires 2 lb. of lime per 1,000 gal. of water treated and that the sludge would concentrate to 15 per cent solids. Computation shows that there would be 5,000 lb. of dried solids, or approximately 3,600 gal. of sludge per million gallons of water treated. This is equivalent to a requirement of approximately 2 acres of lagoons, 2 ft. deep, per year for each million gallons of water treated.

Reburning of lime has been practiced for many years in recausticizing for pulp and paper mills. However, the problems connected with water softening plants are different because of the low tonnages involved, because the magnesium content must be held in check and because space is often limited. For instance, at a paper mill a recausticizing plant burning 40 tons per day would be considered small. Forty tons per day would be high for a water plant, however, for it would be the product of a plant serving a city of from 100,000 to 200,000 population. The majority of cities having water softening plants are smaller than this and must be taken into consideration. It is not practical to make smaller editions of present designs of recalcining plants, because with smaller tonnages the efficiency drops off. It therefore seems desirable to develop new types of

A discussion of papers by Robert T. Sheen and H. B. Lammers and H. V. Pedersen (see page 1145 and page 1170) presented on June 14, 1944, at the Milwaukee Conference by Frederick G. Nelson, Asst. Mgr., San. Div., The Dorr Co., Chicago, Ill.

furnaces better suited to water works practice.

Magnesium may be present in considerable amounts in hard waters and a portion is precipitated as magnesium hydroxide. Unless purged from the system, it soon builds up to a point where it seriously interferes with the treatment process. For that reason some method must be used for continuously removing it from the system; otherwise a considerable portion of new lime must be added to keep the percentage of magnesium within practical limits.

While the question of space may or may not be important, the recalcining furnace must be of such design that it will not mar the architectural appearance of the plant nor cause a dust nuisance.

To reclaim lime economically, the sludge must be partially dewatered by some mechanical means. It is known that the characteristics of sludge at various water softening plants differ radically. While some sludges will concentrate in the sedimentation tanks to 27 to 33 per cent solids, at others it is difficult to obtain 10 per cent solids. There are many factors involved, but from present knowledge, or lack of knowledge, it is questionable whether the percentage of solids in the sludge obtained from any given water can be predicted with any degree of accuracy.

The work that has been done in causticizing sheds some light on the subject. While the investigations were primarily concerned with settling rates of calcium hydrate, there seems to be a very definite connection between settling rates and the percentage of solids to which calcium carbonate will concentrate. In some of the older work we find that Dorr and Bull (1) list fourteen factors affecting settling rates of the hydrate. While many of these do not apply to water softening, the following factors do appear to be important:

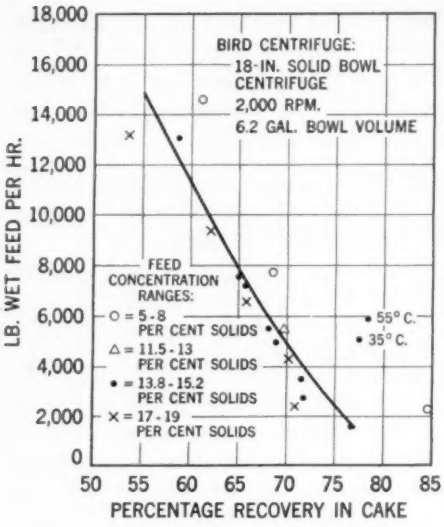
1. The chemical and physical nature of the original limestone.
2. Method of burning.
3. Slaking temperature and amount of water used for slaking.
4. The percentage of magnesium present in the water.

The chemical and physical nature of the original limestone appears to carry through even after reburning of the sludge produced. Therefore, the original source is important.

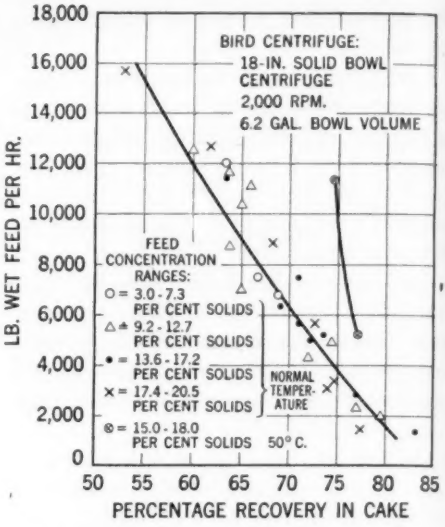
Soft burned lime, according to McAllister (2), gives slower settling rates than does a hard burned lime. Therefore, from the sludge concentration standpoint, the hard burned limes are superior, but it is stated that they do not give as good clarification as the softer burned products.

Dorr and Bull (1) showed that the amount of water used in slaking is very important. They found that a ratio of water to lime of 0.67 : 1 gave settling rates averaging twelve times faster than for a ratio of 4.2 : 1. The latter figure is more nearly in accordance with present water works practice, although some plants use a much higher ratio.

The percentage of magnesium present in the raw water may be a factor and is thought by some to influence slower settling rates. It is the writer's opinion, based on observations at various plants, that this is not necessarily true. At one plant in particular, where the magnesium in the raw water was well over 25 ppm. as Mg, the sludge could be settled to almost any degree of concentration.


BIRD CENTRIFUGE:
18-IN. SOLID BOWL CENTRIFUGE
2,000 RPM.
6.2 GAL. BOWL VOLUME
FEED CONCENTRATION RANGES:
○ = 5-8 PER CENT SOLIDS
△ = 11.5-13 PER CENT SOLIDS
• = 13.8-15.2 PER CENT SOLIDS
× = 17-19 PER CENT SOLIDS
• 55° C.
• 35° C.
LB. WET FEED PER HR.
PERCENTAGE RECOVERY IN CAKE

CURVE 1. Water Softening Sludge. Findlay, Ohio.


BIRD CENTRIFUGE:
18-IN. SOLID BOWL CENTRIFUGE
2,000 RPM.
6.2 GAL. BOWL VOLUME
FEED CONCENTRATION RANGES:
○ = 3.0-7.3 PER CENT SOLIDS
△ = 9.2-12.7 PER CENT SOLIDS
• = 13.6-17.2 PER CENT SOLIDS
× = 17.4-20.5 PER CENT SOLIDS
⊗ = 15.0-18.0 PER CENT SOLIDS
NORMAL TEMPERATURE
50° C.
LB. WET FEED PER HR.
PERCENTAGE RECOVERY IN CAKE

CURVE 2. Water Softening Sludge. Findlay, Ohio.

Regardless of the many factors affecting the concentration of the sludge, in reclaiming it will probably have to be taken about as it is found. Dewatering and reburning equipment should, therefore, be sufficiently flexible to handle a rather wide variety of sludges.

The two methods for partial dewatering which have been tried to date are vacuum filters and continuous centrifuges. Vacuum filters were studied by the Metropolitan Water District of Southern California on Colorado River water and are covered in a very complete report by Aultman (3). The investigation was conducted in the period November 1937—May 1938 and covered the complete problem of sludge reclamation. It included dewatering on vacuum filters, recalcining in the vertical hearth-type furnace, effect of the use of reburned lime on the softening process and removal of magnesium by the Lykken-Estabrook process.

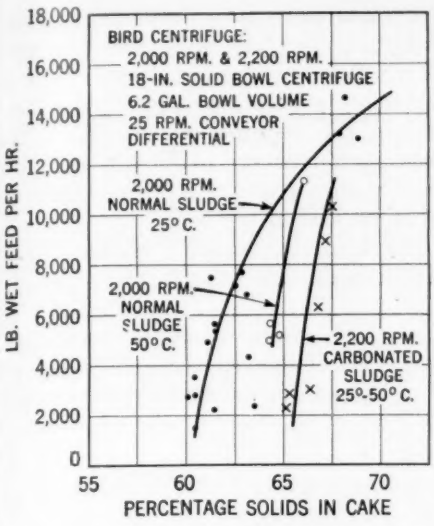
Dewatering with vacuum filters showed that the moisture content could be reduced to approximately 50 per cent and that rates up to 400 lb. of dry solids per square foot of filter area per 24 hr. could be obtained.

Another conclusion reached was that the reburned lime was equal to, or superior to, the original lime. However, unless the magnesium was purged from the system, it very quickly built up to a point where it not only interfered with the softening process but affected the economy of reclaiming.

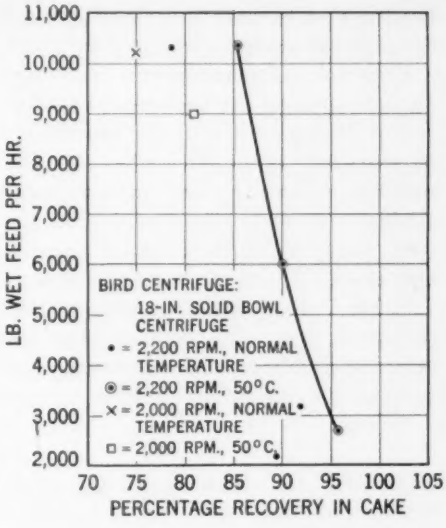
For conditions assumed for the Metropolitan Water District, it was concluded that a definite saving could be made by reclaiming lime.

Findlay, Ohio, Water Plant

During the early part of 1939, a Bird continuous centrifuge was set up and operated by the Development Department of the Dorr Co. at Findlay, Ohio. The Findlay water plant was constructed in 1932 and is of the con-



CURVE 3. Water Softening Sludge. Findlay, Ohio.



CURVE 4. Carbonated Sludge. Findlay, Ohio.

ventional lime and soda-ash type, operating either on well or surface water. A complete description of the plant is given in *Engineering News-Record*, June 30, 1932.

Tests were made with the 18-in. Bird centrifuge to obtain general operating data and to determine the adjustments necessary for best performance. They included studies on heated and carbonated sludges as well as on the untreated sludge.

Curve 1 shows the feed rate vs. percentage of recovery. The feed rate is in pounds per hour of wet sludge fed to the centrifuge. It should be noted that these data were gathered with the centrifuge operating at 2,000 rpm.

Generally the percentage of recovery of solids in the cake was a function of the feed rate as indicated by the curve. However, very low percentages of solids in the feed resulted in somewhat higher recoveries.

Two points are shown for tests on sludge which had been heated to 35°C. and 55°C. respectively, showing a very material increase in recovery.

Curve 2 is similar to Curve 1 except that the speed of the centrifuge was 2,200 rpm. instead of 2,000 rpm. It should be noted that the increased speed also increased the percentage of recovery. Likewise, increased temperature was a factor in increasing the precentage of recovery.

Curve 3 shows the effect of cake moisture vs. feed rates. The percentage of solids in the cake remained relatively constant for various feed rates, particularly on the higher temperature sludges or on sludges which had been carbonated.

Tests were undertaken to determine the effect when a portion of the magnesium was eliminated by carbonation. It was found that the carbonation could be satisfactorily carried out when the sludge was reduced to about 5 per cent solids and carbonation was carried on for 3½ hr. This was done by taking gas from the regular recar-

bonation compressor and distributing it through the sludge with lawn sprayers.

Curve 4 summarizes the centrifuge performance on the carbonated sludge, and it is apparent that the percentage of recovery is much higher on this material than on the uncarbonated sludge. It was also found that the feed would settle to a higher percentage of solids with plain sedimentation.

Table 1 is a general summary sheet prepared from the various data obtained at Findlay. One interesting fact is that the centrifuge rejects a considerable portion of the magnesium, which passes off with the centrate. Thus the centrifuge is shown to be a means of preventing magnesium build-up in the reclamation process. Assuming a recovery of 73 per cent, the magnesium removal is 59 per cent of that present in the feed.

Conclusions drawn from the Findlay experiments were that:

1. The 18-in. diameter centrifuge would deliver about 500 lb. per hr. of dry solids with 61 per cent

TABLE 1

18-in. Bird Continuous Centrifuge Results
Water Softening Sludge—Findlay, Ohio

Feed		Solids—% Effluent	Cake		Percentage of Recovery	Temperature—°C.	rpm.
gpm.	Solids—%		Solids—%	Dry Solids—lb. per hr.			
5.4	12.9	3.9	60.4	282	74.5	14	2000
12.5	18.0	7.6	63.1	810	65.8	14	2000
17.2	17.9	8.1	67.0	1045	62.5	14	2000
24.2	17.8	9.6	68.0	1260	53.7	14	2000
5.3	15.7	4.6	62.0	346	77.0	14	2200
9.7	17.1	5.8	61.7	665	73.5	14	2200
13.8	16.1	5.8	62.0	865	70.9	14	2200
22.9	20.4	9.7	68.1	1573	61.5	14	2200
9.2	15.7	4.3	64.4	613	77.5	35	2000
10.7	16.8	4.5	64.4	770	78.4	55	2000
5.3	29.0	4.6	66.4	840	91.6	14	2200
17.2	28.8	9.2	67.6	2325	78.8	14	2200
4.4	30.4	2.8	65.6	1765	95.5	50	2200
10.2	27.1	4.5	66.8	1490	90.0	50	2200
17.3	28.7	6.7	68.0	2520	85.4	50	2200

Conveyor differential speed 25 rpm. at 2000 rpm. bowl speed.
Bowl volume 6.2 gal.

Power input—3.8 kw. at 2000 rpm.— 5.4 gpm. feed
6.1 kw. at 2000 rpm.—24.2 gpm. feed
4.7 kw. at 2200 rpm.— 5.3 gpm. feed
7.6 kw. at 2200 rpm.—22.9 gpm. feed

At 6.5 gpm., 2200 rpm:

	Feed	Effluent	Cake
Ca—%	33.60	27.96	35.56
Mg—%	3.91	8.58	2.23
Inerts—%	0.53	0.69	0.65
R_2O_3—%	1.10	2.48	0.78

TABLE 2

Performance Tests of Bird Continuous Centrifuge

Kankakee, Illinois

Date	Feed			Cake		Percentage Recovery
	Wet—*lb./hr.*	Solids—%	Temperature—°F.	Dry Solids—*lb./hr.*	Solids—%	
Jan. 8, 1941	159	25.5	34	2200	65.6	90.5
Jan. 25, 1941	162.2	27.5	—	2670	67.5	71.5
Marshalltown, Iowa						
Jan. 11, 1944	222	9.5	53	1030	64.0	80.0

solids in the cake, representing a recovery of 75 per cent of the feed solids.

2. The capacity was increased by increasing the feed rate but with a resulting lower recovery.
3. Reduction of the magnesium content in the sludge greatly improved the capacity, recovery and percentage of solids in the cake.
4. Cake capacities as high as 2,300 lb. per hr. of dry solids with a solids content of 67 per cent and a recovery of 79 per cent were obtained on sludges which had been carbonated to remove some of the magnesium.
5. Likewise, when the feed rate was reduced to yield 765 lb. per hr. of dry solids, recoveries as high as 95 per cent were obtained.

Table 2 shows typical results at Marshalltown, Iowa, and Kankakee, Ill. The plant at Kankakee takes water from the Kankakee River. The water was relatively hard and turbidities averaged around 50 to 100 ppm. at the time of year the tests were run. It is softened with lime and coagulated with alum. The centrifuge was installed on an experimental basis and at the conclusion of the tests was purchased by the Kankakee Water Co.

The averages of several tests are shown for Kankakee. It should be noted that capacities were considerably higher than for Findlay, and the percentage of recovery of solids was generally much higher.

At Marshalltown the solids in the feed are low at 9.5 per cent, but a recovery of 80 per cent for a yield of 1,030 lb. per hr. of dry solids was considerably greater than results at Findlay.

Table 3 gives a typical analysis of sludges and of the feed, centrate and cake at Marshalltown and at Wright Aeronautical Corp. It should be noted that the centrifuge throws out with the centrate a relatively high percentage of the magnesium. This is in accord with the tests conducted at Findlay.

The statement was made earlier that approximately 2.5 lb. of dry sludge is produced for each pound of CaO used. A sludge balance was computed and the results for an assumed analysis of the raw and unsettled water for Marshalltown are shown in Table 4. The

TABLE 3

Typical Analysis of Water Softening Sludges Dewatered by Bird Continuous Centrifuge

Marshalltown, Iowa
January 13, 1942

Sample	Feed	Centrate	Cake
Fe_2O_3	1.6	4.8	1.6
$CaCO_3$	81.0	56.5	89.5
$Mg(OH)_2$	7.3	12.3	3.8
November 17, 1943			
$CaCO_3$	75.6	80.6	92.4
$Mg(OH)_2$	17.4	13.9	3.6
Wright Aeronautical Corp.			
Sample	Feed	Centrate	Cake
Fe_2O_3	0.40	3.28	0.52
R_2O_3 (Oxides of Fe and Al)	1.35	5.16	0.90
$CaCO_3$	87.50	73.90	89.80
$Mg(OH)_2$	8.00	13.20	6.07

TABLE 4

Marshalltown, Iowa
Sludge Balance—Based on 2-Mgd. Rate

Assumed Analysis of Water

	Raw Water—ppm.	Settled Water—ppm.
CO_2, as CO_2	17	0
Total Hardness, as $CaCO_3$	340	75
Calcium, as $CaCO_3$	240	35
Magnesium, as $CaCO_3$	100	40
Alkalinity—*M*	300	55
Alkalinity—*P*	0	37.5

Sludge Balance

Lime Required lb./day		Lime Produced lb./day	
CaO	90% CaO	CaO	80% CaO
3900	4300	3920	4900

* On Basis of 80% Recovery of Calcium in Centrifuge.

actual analysis of Marshalltown water is not constant as it depends upon what wells are in use. Therefore, a hypothetical analysis which approximates actual conditions was assumed in working out the sludge balance. For these conditions, the CaO produced is approximately equal to that required.

Conclusions

1. To reclaim lime economically, the sludge must be partially dewatered by centrifuge, vacuum filter, thickening or some other mechanical means.

2. For most sludges it is necessary to control magnesium and other diluting materials in order to recover a high calcium lime. The continuous centrifuge is a means of purging the system of these materials.

3. Carbonation before thickening of sludges is a means of controlling magnesium and improves their settleability.

4. For conditions as assumed for Marshalltown, the sludge balance shows sufficient recoverable lime to supply the plant requirements.

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2. McAllister, R. W. Useful Properties of Lime. Rock Products, **45**: 48 (1942).
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Influence of Various Chemicals on Palatability of Drinking Water

By J. W. Hassler and Martin Faye

DURING the past thirteen years, the Industrial Chemical Sales Division of the West Virginia Pulp & Paper Co. has participated in many studies dealing with the removal of tastes and odors from water supplies. Early investigations were conducted at the home laboratories using samples of water sent in from various municipalities throughout the country. The threshold numbers of the finished waters (when received) agreed closely with those reported by the plants, indicating that the plant treatment had stabilized the water. However, such correlation was lacking on the raw water samples. This was attributed to changes occurring during transit, since the odor intensity of these samples continued to change after they were received. Such changes in the raw water made it difficult to correlate plant operation with remote laboratory tests and it was concluded that dependable data could be obtained only by conducting the tests directly at the site of each supply. Since then many investigations have been made at various plants to answer individual questions and problems.

Several years ago, E. A. Sigworth planned and organized a systematic study designed to measure the effect on odor that results from the chemical agents normally employed in water purification. In 1942–1943 Martin Faye made a thorough study, on a laboratory scale, at sixteen filter plants. These plants were located in the states of Pennsylvania, Virginia, Maryland, New Jersey, Maine, Kentucky, Indiana and Michigan. The work covered different types of water supplies involving various sources of contamination. At each plant, the chemical dosage normally used was employed in the study and at those places where some of the chemicals under study were not being used, a suitable dosage was adopted.

The plants are coded by number and Table 1 shows certain characteristics of each water supply together with some pertinent information on the chemicals used in the plant treatment. The odor numbers were determined by the Short-Parallel threshold method [1]

A paper presented on June 14, 1944, at the Milwaukee Conference by John W. Hassler, Director of Research, Industrial Chem. Sales Div., West Virginia Pulp & Paper Co., New York, N.Y.; and Martin Faye, Chem. & Eng. Service, Industrial Chem. Sales Div., Cleveland, Ohio.

[1] This method has been described in the Committee Report, A.W.W.A., Jour. A.W.W.A., **38**: 1173 (1938). Improvements of the method were later discussed in *Taste and Odor Control in Water Purification,* Industrial Chemical Sales Div., West Virginia Pulp & Paper Co., (1942) p. 30.

TABLE 1

Characteristics of Water Supplies and Data on Chemical Treatment

Plant No.	Range of Threshold Odor—Raw	Type of Odor	Coagulation Stage—ppm.		Ammonia—ppm.		Chlorine—ppm.		Carbon—ppm.	Lime After Filtering—ppm.	pH		Pumpage—mgd.
			Alum	Lime	Pre-	Post-	Pre-	Post-			Raw Water	Delivered Water	
1	19–22	Musty	15	0	0	0	0.52	0.52	0	0		6.7	36
2	19–26	Piney	0	0	0	0	0.54	0	0	0			170
3	40–60	Dec. veg.	21	0	0.35	0	2.8	.44	0	22		8.6	—
4	90–110	Dec. veg.	60	8.0	0.12	0	17.3	1.4	0	0	6.0	7.0	10
5	40–60	Earthy	42	6.7	0	0	0	1.7	2.7*	12			12
6	70–100	Musty	30	0	0.42	0	1.14	0.4	6.0*	7	6.5	6.2	2
7	110–125	Chemical	15	0	0	0.18	1.2	0.3	4.2†	6	6.8	7.4	1
8	80–100	Musty earthy	45	0	0	0	3.4	0.7	2.1†	0	7.1	6.1	22
9	12–14		29	0.25	0	1.7	2.8	2.2	8.6*	15	6.7	7.6	4
10	250–270	Chemical	34	0	0	0	3.0	0.3	0	16	6.5	7.7	8
11	26–40	Dec. veg.	20‡	19	0	0.2	6.0	0.4	2*	0	8.1	8.0	5
12	160–220	Dec. veg.	35‡	24	0	0.3	4.5	0.4	6*	0	—	—	5
13	261	Musty	30	0	0	0.2	5.0	0.7	0	0	8.1	7.7	7.7
14	110–125	Oil ref. waste	4.5‡	1.4	0	0.2	1.0	0.5	14*	0	—	—	20
15	1500–2500	Chemical	0	180	0	0	0	1.1	9†	0	8.0	9.2	36
16	60–80	Oil ref. waste	32	22	0	0	0	0.7	7	0	7.1	8.0	

* Applied to raw water.
† Applied at coagulation basin.
‡ Ferric sulfate.

using two men—the "blindfold technique." The results of the various treatments are expressed not in terms of the resulting threshold number (except in Tables 1 and 5) but instead are stated as the remaining or resulting percentage of the raw water odor (which in each case is assigned a value of 100). Thus, on a raw water with a threshold number of 50, if treatment "A" reduced this to 25 and treatment "B" intensified it to 100, such results would be here expressed as: treatment "A" changed the odor to 50 per cent of the raw and treatment "B" to 200 per cent. Such use of a percentage basis for expressing odor changes is not new, having been suggested by M. M. Braidech some years ago. It permits a clearer presentation of an investigation conducted over a period of time during which minor changes can occur either in the sensitivity of the operator or in the intensity of the odor of the raw water. It should be emphasized that any numerical calculation comparing the effect of different treatments on the odor of any supply is valid only when the raw water is reasonably uniform during the study, and it is particularly important to exclude any comparisons where the type of odor in raw water changes during the course of the test.

Many of the chemicals studied made no appreciable change in odor intensity of any supplies. This was true of chemicals used for coagulation, such as ferric salts, alum, alum and soda, etc. Also, coagulation had no effect on the action of active carbon, provided care was taken to allow the carbon to have sufficient time to do its work before being occluded in the floc.

Lime is employed in water purification for purposes other than odor control but as a matter of information a study was made of the influence of this chemical using a dosage of approximately 100 ppm. The results can be briefly summarized: Lime increased the odor in one supply, decreased it

TABLE 2

Influence of Chlorine and Ammonia-Chlorine Plants Arranged in Order of Effect of Chlorine on Intensity of Odor

Plant No.	Odor After Chlorine*— *percentage*	Odor After Ammonia-Chlorine*— *percentage*	Chlorine Dosage— *ppm.*	NH_3:Cl_2 Ratio
11	430	200	8.5	1:4
4	310	160	17.0	1:14
3	160	140	2.8	1:7
14	160	120	1.0	1:2
9	140	100	5.0	1:3
13	140	140	5.0	1:4
12	140	100	4.5	1:4
8	140	100	3.4	1:4
6	140	70	1.2	1:3
1	120	—	0.5	—
7	100	70	1.2	1:2
10	100	70	3.0	1:4
15	100	100	1.1	1:4
2	100	—	0.5	—
16	85	70	0.7	1:4
5	70	50	1.7	1:2

* Odor values expressed as a percentage in terms of raw water taken as 100 per cent.

(20 to 40 per cent) in three supplies and made no change in twelve. Carbon in conjunction with lime usually gave additive results, that is, where lime alone increased the odor, then more carbon was required to remove the odor and where lime alone reduced the odor less carbon was required than on the raw water. On three of the supplies where lime made no change in the odor intensity there was an indication that the odor was less readily adsorbed by active carbon. In other words, on those three supplies, the lime, even though it made no change in the odor intensity, had altered certain characteristics of the odor-producing substances which made them less readily adsorbed.

A study was made of the influence of chlorine using the dosage normally employed at the plant for disinfection (Table 2). Such use of chlorine frequently intensified the odor. There was no parallel between the change in odor and the amount of chlorine needed for disinfection of the supply. Also, the threshold odor of the raw water had no bearing on the resulting change in odor produced by chlorine. All of this would be expected, since the effect of chlorine depends on the change produced in the chemical structure of each specific odor-bearing substance. In view of the multitude of substances that can and do cause tastes and odors it is apparent why the influence of chlorine varies from one supply to another.

Table 3 shows the effect of adding active carbon to raw vs. chlorinated water. On supplies where chlorination intensified the odor, a relatively greater amount of carbon was needed on the chlorinated than on the raw water. (For a true comparison, all filtrates are post-chlorinated and then de-chlorinated.) On the three plants where chlorination by itself made no change in odor, the carbon was slightly more effective on the chlorinated water, indicating that chlorination made these odor-bearing substances more adsorbable. Other independent studies have found some supplies where chlorination decreased the adsorption, so the influence of chlorine on adsorbability appears to depend on the character of the odor-bearing substances. Such an effect is a matter of practical importance since it affects the selection of the best order of applying carbon and chlorine. The answer is an individual one to be found only by a simple study at any plant.

The influence on odor of adding ammonia with chlorine is shown in Table 2. The ammonia dosage was that em-

ployed in the plant. For those plants which were not using ammonia—a ratio of 1 part of NH_3 to 4 parts chlorine was employed. On almost every supply the use of ammonia-chlorine for disinfection gave better results on odor than did chlorine. In some cases ammonia-chlorine reduced the odor below that of the raw water. Any explanation for such reduction is a pure speculation, since we have only very meager knowledge of the chemistry of the action of chlorine or ammonia-chlorine on the many and varied odor-bearing substances occurring in water supplies. One speculation could be that chlorine, when used alone, increases the odor of some substances and decreases the odor of others, and the observed effect of chlorine is a net result. When ammonia is added with chlorine it suppresses the intensification of some odors but could possibly take some advantage of the effect of chlorine on that portion of the odors which are reduced in intensity. The net result would be an over-all improvement in odor.

TABLE 3

Odor Reduction Produced by Carbon on Chlorinated vs. Raw Water

ppm. Nuchar Special	Plant No.															
	11	4	3	14	9	13	12	8	6	1	7	10	15	2	16	5
0	430*	310*	160*	160*	140*	140*	140*	140*	140*	120*	120*	100*	100*	100*	85*	70*
2	310* 70					85* 45		70* 70								
3		120* 60	120* 50			70* 45			85* 45	106* 85		30* 40		100* 100		30* 45
4					85* 60			60* 60			50* 30					
6		70* 45	85* 50				100* 50		70* 30	60				85* 85	50* 50	25* 40
9	140* 30	60* 40	60* 50	70* 40	85* 50		70* 30	40* 30		45*	40* 20	15* 30	15* 30	60* 70		15* 25
12				30* 15			45* 15		60* 12		20* 10				30* 40	
18				20* 10									12* 18		25* 30	
27													4* 6			

(Values represent odor intensity after treatment expressed as a percentage of the raw water. Asterisk represents treatment of chlorinated water. Other figures are for treatment of raw water.)

Table 4 shows the relative value of adding carbon to the raw water as compared with the addition of a similar carbon dosage after chloramine. On those supplies where ammonia-chlorine alone reduced the odors, carbon plus ammonia-chlorine was more effective for reducing odor than carbon alone. Even where ammonia-chlorine by itself did not change the odor, e.g., plant Nos. 8 and 15, it still enabled carbon to do a better job. Probably this is due to increased adsorbability of odor-bearing compounds after application of ammonia-chlorine. The only supplies on which it was more advantageous to apply carbon without ammonia-chlorine were those where ammonia-chlorine by itself intensified the odor. It should be pointed out that at each of the plants the study was made using only a single ammonia-chlorine ratio, generally the one in use at that plant. Other experience has shown that there is no fixed ratio for all conditions and active carbon has frequently been enabled to accomplish far better results by the simple ex-

TABLE 4

Odor Change Produced by Carbon on Raw Water and Also After Ammonia-Chlorine

ppm. Nuchar Special	Plant No.													
	11	4	3	13	14	12	8	15	9	10	7	16	6	5
0	200*	160*	140*	140*	120*	100*	100*	100*	100*	70*	70*	70*	70*	50*
2	140* 70			85* 45			50* 70							
3		50* 60	50							30* 40			30* 45	20* 45
4	120* 70						40* 60		60* 60		25* 30			
6		30* 45	40*			70* 50				25* 30		40* 50	25* 30	20* 40
9	85* 30				45* 40	50* 30	20* 30	15* 30	60* 50		17* 20			15* 25
12					20* 15	30* 15			45* 50	15* 15	15* 10	30* 40		
18					10* 10			10* 15				17* 30		
27								4* 6						

(Values represent odor after treatment expressed as a percentage of the raw water odor. Asterisk indicates chloramine used in conjunction with carbon. Other figures are for carbon alone.)

TABLE 5

Influence of Breakpoint Chlorination on Odor Reduction

Plant No.	Cl_2 to Reach Breakpoint—ppm.	Residual Cl_2 at Breakpoint—ppm.	Threshold Odor Number		Type Odor		Approximate ppm. Nuchar Special Needed in Conjunction With Ammonia-Chlorine to Obtain Equivalent Odor Reduction
			Raw	At Breakpoint	Raw	At Breakpoint	
1	5.0	2.92	22	16	Musty earthy	Woody chlorophenol	4
2	6.0	1.03	26	14	Piney	Chlorophenol	—
3	5.5	1.78	22	19	Dec. veg.	Dec. veg.	1
4	16.0	0.53	95	60	Dec. veg.	Woody	2
5	5.5	0.18	60	19	Earthy	Earthy	2
6	6.0	0.36	95	22	Musty	Woody	6
7	14.0	0.53	110	40	Musty chemical	Musty chemical	3
8	5.0	0.18	190	80	Musty earthy	Musty woody	2
10	8.0	0.71	270	95	Chemical	Musty	2

pedient of using a more suitable ammonia-chlorine ratio than the one in previous use.

Another point in favor of the use of chloramine for disinfection when carbon is applied later has been suggested by Charles Spaulding. Unlike chlorine, chloramines do not react with carbon, and they are not appreciably adsorbed. Therefore, the use of carbon with chloramine does not provide any difficulty in maintaining safe chlorine residuals in the finished water. Spaulding's observation has been confirmed by our own experience.

Breakpoint chlorination was studied in nine plants. It will be recalled that simple chlorination generally resulted in an increased odor but the use of breakpoint chlorination improved the odor in every case studied. Table 5 shows that improvement was appreciable in some cases and small in others. On all the supplies equivalent odor removal was obtained by the use of carbon in the dosage shown in Table 5. The degree of improvement that can be obtained by breakpoint chlorination alone is fixed, whereas with chloramine and carbon a greater degree of improvement can be obtained by using greater quantities of carbon. Of course there is no inherent reason why carbon cannot be used in conjunction with breakpoint chlorination. It has been and is being so used. It is just a question of certain practical problems. If carbon is added before breakpoint chlorination, time and facilities must be provided to settle out the carbon before the chlorine is added in order to avoid de-chlorination by carbon and a waste of chlorine. For a similar reason, if carbon is applied after breakpoint chlorination, sufficient time must be allowed to complete the breakpoint reaction before adding carbon. No one can claim these obstacles are insuperable, but certainly they do not provide the convenience afforded by chloramine and carbon.

The foregoing deals with the effects on palatability. It is always essential to make certain that local conditions permit the use of chloramines for disinfection.

Threshold Odor Tests

In studies on palatability it is necessary to recognize certain limitations in the use of a test that measures odor intensity. Some odors and tastes are more objectionable than others. Moreover, in some supplies the odor and taste intensity are not entirely correlated. Inasmuch as changes can occur in a raw water that are not revealed by an odor test, and the test itself is subject to certain errors, it follows that one must avoid placing undue emphasis on any single result. In spite of all these limitations, however, wide experience with the threshold test has demonstrated that the trend revealed by a number of tests will provide a very practical guide in the selection of the best treatment to improve the palatability of any individual supply.

To summarize the results of this work it can be stated:

1. Coagulating chemicals, including alum and ferric salts, do not influence odor changes and need not affect the ability of carbon to remove tastes and odors.

2. Lime in dosages sufficient to change pH sometimes alters the intensity of an odor and may influence the effect of active carbon.

3. Chlorine in dosages which disinfect water usually produces an intensification of odors, if initially present in the raw water. In some cases the chlorinated odor is easier to remove with carbon and in other cases it is more difficult to remove. The best point of carbon application in such cases can be determined by a test at the individual plant.

4. Breakpoint chlorination generally reduces the odor intensity. Sometimes the improvement is appreciable and in other cases is only slight.

5. From the point of view of palatability, disinfection with chloramine is desirable since it minimizes any intensification of odors and generally aids in the removal of odors by carbon. Chloramine appears to assist in the removal of odors.

Destruction of Micro-Organisms

By Shih Lu Chang

ALTHOUGH chlorine compounds have been used as germicidal agents for more than half a century since Koch (1) first studied the germicidal action of hypochlorite in 1881, we are still uncertain how chlorine and chloramine compounds destroy micro-organisms in water. The opinions expressed by different investigators may be included under any of the following three theories:

a. *The Nascent Oxygen Theory.* Chlorine compounds owe their germicidal property to the hypochlorous acid formed, which liberates nascent oxygen to destroy micro-organisms.

b. *The Nascent Oxygen and Direct Chlorination Theory.* Chlorine compounds destroy micro-organisms in water not only by the nascent oxygen liberated by the hypochlorous acid but also by direct chlorination of the protoplasm of the organisms.

c. *The Formation of Toxic Substance Theory.* Chlorine compounds destroy micro-organisms by chlorinating the lipoid-protein substance in the bacterial cell wall, to form some toxic chloro-compound which interferes with further cell division, stops regeneration, and results in the death of the organism.

A paper presented at the Milwaukee Conference on June 13, 1944, by Shih Lu Chang, Research Fellow in San. Eng. and in Comparative Pathology and Tropical Medicine, Dept. of San. Eng., Graduate School of Eng., Harvard Univ., Cambridge, Mass.

The "Nascent Oxygen" Theory

Ever since Jakowkin (2) established the existence of hypochlorous acid when gaseous chlorine is dissolved in water, most investigators have believed that the bactericidal activity of chlorine in water is due to the hypochlorous acid thus formed. The germicidal property of hypochlorite of various forms has also been attributed to the formation of hypochlorous acid. Andrewes and Orton (3) found that, upon acidification, the bleaching and germicidal powers of a hypochlorite solution are greatly increased and concluded that the increase in germicidal power is a result of the liberation of hypochlorous acid. Other investigators (4, 5, 6, 7, 8, 9) observed the same effect by acidifying hypochlorite solutions and reached the same conclusion as that of Andrewes and Orton.

How hypochlorous acid destroys micro-organisms has never been demonstrated experimentally, due apparently to the small size of the organisms involved and the difficulty of detecting any chemical and structural changes in such small organisms. However, it has been thought by most investigators

that hypochlorous acid achieves its destruction by liberating nascent oxygen according to the following reactions:

1a. $Cl_2 + H_2O \rightleftarrows HOCl + HCl$, or

1b. $OCl^- + H^+ \rightleftarrows HOCl$

2. $HOCl \rightarrow HCl + O$

The nascent oxygen, thus liberated, oxidizes the protoplasm and renders the organism non-viable. This theory, now regarded as being old-fashioned, still has its place in the field of disinfection, although it does not explain the destruction of organisms under all circumstances.

The "Nascent Oxygen" and Direct Chlorination Theory

The demonstration of the germicidal property of certain chloramines made the "Nascent Oxygen" theory debatable. The possibility of the formation of hypochlorous acid by hydrolysis of monochloramine according to the following reaction

$$NH_2Cl + H_2O \rightarrow HOCl + NH_4OH$$

was considered by Holwerda (10) who, however, failed to detect any HOCl present in a chloramine solution containing 10 ppm. of available chlorine. Furthermore, oxidizing substances such as H_2O_2 and $KMnO_4$, were found by some workers (11, 12) to be much less germicidal at concentrations yielding far more nascent oxygen than hypochlorous acid; also chlorine was found (13) to satisfy the bio-oxygen demands of sewage far out of proportion to the amount of oxygen available from the hypochlorous acid formed. These facts led to the more modern belief that chlorine compounds destroy micro-organisms both by oxidation by the nascent oxygen from HOCl and by direct chlorination of the protoplasm of the organism. The bacteriologist's viewpoint may be illustrated by the statement made by McCulloch (13): "Certainly oxidation has a part in the destruction of bacteria when they are exposed to action of chlorine solutions, although there is evidence that direct chlorination of the plasma of the bacterial cell also is important." [By oxidation, the author meant oxidation by nascent oxygen. In chemical parlance, direct chlorination, involving reduction and increase of valences of the reactants, is also a process of oxidation.]

The Formation of Toxic Substance Theory

Basing his opinion on the fact that chlorine, when added to sewage, combines with the ammonium compounds to form chloramines which, though losing their oxidizing power, still exert germicidal effect in the sewage, Baker (14), in 1926, advanced the theory that chlorine compounds destroy bacteria by combining with the lipoid-protein substance in the bacterial cell wall to form some chloro-compound. This interferes with further cell division, stops regeneration, and results in the death of the organism. Baker's theory was first favorably commented upon by Howard (15) and supported by Braidech (16) and many others. Recently, in discussing Costigan's report on "Bacteria and Chlorine" (17), Krasauskas (18) said that he believes that Baker's theory of toxic-substance formation represents the most probable mechanism of destruction of bacteria by chlorine compounds. He quotes as evidence to support Baker's theory the observation made by the U.S. Public Health Service (18) of the disintegration of bacteria subjected to chlorine treatment.

Lacking any direct experimental evidence, these theories described above are merely deductions or suppositions based on the possible chemical reactions of chlorine compounds on organic substances. The fact brought out by Krasauskas (18) that bacteria disintegrate with chlorine treatment may just as well be considered as evidence of the destruction of bacteria directly by the chlorine.

In a previous paper (19), the writer showed that, by using ortho-tolidine solution, penetration of chlorine into the cysts was demonstrated when large doses of chlorine as gaseous chlorine and HTH and chloramines were used at pH 5.0, and the penetration of chlorine increased with increase in chlorine dosages and contact periods. It was also shown that the cyst-penerating power of chloramines was much weaker than that of gaseous chlorine and HTH. The writer also showed in the same report that destructive changes of nuclei of the cysts were noticed in the chlorinated cysts. From these preliminary results, it seems that, in the process of destruction of micro-organisms by chlorinating agents, there is a penetration of chlorine into the organisms and that the cytological changes noticed in the chlorinated cysts indicate that the death of the cysts is probably a result of these structural changes.

In the present study, more extensive tests were made in addition to these preliminary ones in attempting to solve a few important and fundamental problems concerning the mechanism of death of micro-organisms exposed to chlorine and chloramine compounds. Such problems are:

a. Do different chlorine and chloramine compounds differ in their penetrating power?

b. Do differences in cysticidal (or germicidal) power of different chlorine and chloramine compounds ever run parallel with the cyst-penetrating power of these compounds?

c. How do the pH and the contact period affect the cyst-penetrating powers of different chlorine and chloramine compounds?

d. Does the supposed "nascent oxygen" liberated by HOCl play any significant part in the process of destruction of micro-organisms?

e. Is destruction or poisoning the actual cause of death of micro-organisms exposed to chlorine and chloramine compounds?

It was felt that if these problems could be fairly well solved, much doubt and speculation could be cleared and a sound foundation could be laid in the theory and practice of chlorination or chloramination of water.

Procedure and Materials

The procedure of producing cysts in culture, for preparing cyst suspension, for chlorination, de-chlorination, determination of initial and residual chlorine and testing the viability of the treated cysts were essentially the same as those described in previous reports (19, 20). To detect the penetration of chlorine into cysts, the procedure is as follows:

Forty-ml. portions of various solutions of chlorine and chloramine compounds at desired concentrations of titratable chlorine and at desired pH values were dispensed in 50-ml. centrifugal tubes. These were allowed to stand for 4 hr. to allow Cl_2, HOCl, OCl^-, $NHCl_2$ and NH_2Cl and hydrolysis products of organic chloramine compounds, if any, to reach equilibrium. These tubes were stoppered to prevent loss of Cl_2 and HOCl and absorption

of CO_2 from the air. Five drops of a cyst suspension, containing 10,000 to 50,000 cysts, were added to each tube and the contents agitated. After the desired contact period, the contents were centrifuged and the sediments washed with distilled water a few times to remove most of the residual chlorine. The sediment in each tube was then mixed with 5 ml. of distilled water to which was added a drop of ortho-tolidine solution. The suspension was centrifuged and washed once or twice to get rid of the yellow liquid. The sediment was finally suspended in $\frac{1}{2}$ ml. of distilled water and examined for yellow-stained cysts. It was found that cysts that were not exposed to chlorine failed to show any yellow discoloration upon adding the ortho-tolidine solution. Best results were obtained when the microscopic examination was made within 30 min. and with the aid of a light filter.

The procedure for studying the structural changes associated with death of cysts may briefly be described as follows:

A series of cyst-water samples were dosed with chlorine and chloramine compounds from a calculated minimal cysticidal dose up to a point three or four times the minimal cysticidal, with the doses at 0.5 ppm. of titratable chlorine apart. After the desired contact period, the samples were de-chlorinated with sodium-thiosulfate solution, centrifuged and washed once with distilled water. Part of the sediment was inoculated in a tube of liver infusion agar medium (seeded with a bacterial flora) to test the viability and locate the minimal cysticidal dose, and part of it was smeared on slides with egg albumin, fixed in Schaudinn's fluid, and stained by the iron-hematoxylin method and examined under oil immersion.

To regulate the pH, 0.01 *N* and 0.1 *N*, HCl and NaOH solutions were used and checked with a glass electrode. The titratable chlorine was determined by the acid-starch-iodide method.

Penetration of Chlorine Into Cysts of *E. histolytica*

In the following study, solutions of gaseous chlorine, high test hypochlorite (hereafter referred to as HTH), chloramines (prepared from solutions of gaseous chlorine as NH_4Cl in ratio of $Cl:NH_3 = 4:1$), Halazone (prepared from tablets containing 0.004 g. *p*-sulfone-dichloramido-benzoic acid), and succinchlorimide were used. All tests were made at 25°C. with initial concentrations of 12.5, 25, and 50 ppm. of titratable chlorine at pH values of 1.0 (this pH was omitted in preparing the ammonia-chloramines), 5.0, and 8.5, and with contact of 10 and 20 min.

These pH values were selected in order to study the relative penetrating power of Cl_2, HOCl, OCl^-, $NHCl_2$, and NH_2Cl. From the hydrolysis constant of Cl_2, which is 4.48×10^{-4} at 25°C. as given in the International Critical Tables, and from the dissociation constant, which is 5.60×10^{-8} at 25°C. as calculated by Skrabal and Berger (21), it was calculated that in a solution of gaseous chlorine or HTH (at equilibrium), 15 per cent of the chlorine exists as Cl_2 and 85 per cent as HOCl at pH 1.0; at pH 5.0, practically all the chlorine exists as HOCl; and at pH 8.5, 10 per cent of the chlorine exists as HOCl and 90 per cent as OCl^-. From the study on chloramines by Tilley and Chapin (5), it is apparent that in a solution of chloramines, dichloramine is practically the only component at pH 5.0 and monochloramine at pH 8.5. A total of five tests was made on each series of pH

values. The averages of the results are presented in Table 1.

Before discussing the table, it must be noted that these yellow-stained cysts indicated the presence of a considerable amount of chlorine inside the cysts, since a light yellow color is not detectable under the microscope. Hence, those cysts which failed to show a distinct yellow color were not necessarily failing to show penetration by chlorine.

In the table, several interesting points are noticed. First, it is seen that, in general, there was a consistent increase in percentages of yellow-stained cysts with each increase in the dosage of titratable chlorine, with each lowering of pH value and with each increase in contact period. The sharp increase in percentages of yellow-stained cysts in solutions of gaseous chlorine and HTH from pH 8.5 to pH 5.0 clearly shows that, within this pH range, or when free chlorine does not exist in appreciable amounts, the cyst penetration by chlorine compounds depends chiefly, if not entirely, on the amount of HOCl present, and that the hypochlorite (OCl^-) is probably inactive. The percentages of yellow-stained cysts in both solutions of gaseous chlorine and HTH were about the same under similar conditions, indicating that these two chlorine compounds have apparently the same amount of active chlorine (Cl_2 and HOCl) when the Cl_2, HOCl, and OCl^- are in equilibrium. The absence of yellow-stained cysts in solutions of gaseous chlorine

TABLE 1

Percentages of Cysts Showing Excess of Chlorine After Exposure to Chlorine Solutions, HTH, Chloramines, Halazone, and Succinchlorimide

Type of Chlorine or Chloramine Compound	Doses of Titratable Chlorine in ppm.		Percentages of Yellow-Stained Cysts					
			10-Min. Contact			20-Min. Contact		
	Initial	Residual	pH 1.0	pH 5.0	pH 8.5	pH 1.0	pH 5.0	pH 8.5
Gaseous Chlorine	12.5	9–11	12±2.0	10±1.8	0	17±2.1	14±1.6	0
	25.0	20–23	32±3.1	28±2.6	0	44±3.8	42±3.5	0
	50.0	45–48	68±4.2	62±3.8	3±0.4	83±4.6	78±4.5	5±0.8
HTH	12.5	9–12	11±1.6	11±2.0	0	18±2.1	15±1.8	0
	25.0	21–24	30±2.4	27±2.5	0	46±2.8	42±3.0	0
	50.0	43–49	68±3.8	62±3.6	4±0.8	84±4.2	80±3.8	6±1.0
Chloramines	12.5	11–12	—	2±0.6	0	—	4±0.8	0
	25.0	22–24	—	7±1.6	0	—	12±1.8	0
	50.0	46–49	—	20±2.5	4±1.0	—	30±2.8	7±1.2
Halazone	12.5	10–12	4±0.8	3±0.6	0	6±1.0	5±0.8	0
	25.0	21–24	12±2.3	10±1.8	0	18±2.8	16±1.8	0
	50.0	42–48	26±3.2	22±2.0	2±0.5	32±2.8	30±2.8	5±0.8
Succinchlorimide	25.0	22–24	0	0	0	0	0	0
	50.0	46–49	0	0	0	0	0	0
	100.0	86–92	5±1.5	4±0.8	3±0.6	6±1.6	4±1.0	4±0.8

and HTH at pH 8.5 even at an initial chlorine of 25 ppm., and the sharp jump of the percentage of yellow-stained cysts at pH 1.0 and 5.0 indicate that below a certain concentration of active chlorine excess of chlorine failed to enter the cysts, and that above a certain concentration of active chlorine, large numbers of cysts were penetrated by an excess of chlorine.

Second, it is noticed that, in solutions of gaseous chlorine and HTH at pH 1.0, there were consistently higher percentages of yellow-stained cysts than at pH 5.0. Although the difference in several cases was not statistically significant, the consistency seems to indicate that free chlorine (Cl_2) is not only just as powerful as, but even slightly more powerful than, HOCl, since, as stated before, at pH 1.0, 15 per cent of the chlorine exists as Cl_2 and 85 per cent as HOCl, while at pH 5.0, practically all chlorine exists as HOCl. The effect of HCl on the cysts may be excluded from consideration because of the fact that a 0.1 *N* HCl solution has been found repeatedly to show no harmful effect on cysts with contact periods of 20 and 30 min. (from the writer's unpublished data).

Third, as shown in the table, the chloramines, even under similar conditions, have a much weaker cyst-penetrating power than chlorine water and HTH. The dichloramine was found to be more powerful than the monochloramine. As will be shown later, the greater cyst-penetrating power of dichloramine is apparently due to the fact that dichloramine hydrolyzes into monochloramine and HOCl, while the monochloramine shows no hydrolysis even after a period of 2 hr. At pH 8.5, the cyst-penetrating power of solutions of gaseous chlorine and of HTH did not differ significantly from that of monochloramine. That of all three was negligible.

Fourth, it will be noted that Halazone had a cyst-penetrating power approximately two-fifths that of gaseous chlorine and HTH under similar conditions, and that the effect of pH on the cyst-penetrating power of Halazone was about the same as that on chlorine water and HTH. However, it should be mentioned that in the present study, the solution of Halazone used had been allowed to stand for 2 hr. Since Halazone dissolves very slowly in water, the cyst-penetrating power of Halazone would be even weaker than that of chlorine water of HTH if the tablets were used instead of the solution.

The fifth point of interest is that with the succinchlorimide solution, even up to a concentration of 50 ppm. of titratable chlorine, no excess of chlorine was demonstrated in most of the cysts. The effect of the pH on the cyst-penetrating power of succinchlorimide is not apparent from the table, although it seemed that at pH 1.0 the penetrating power was better than at higher pH values. This, as will be shown later, is entirely due to the fact that the succinchlorimide does not hydrolyze in water to any detectable extent. This was observed over a period of 2 hr. except at pH 8.0 where a trace of hydrolysis was noticed. Therefore, it seems that succinchlorimide, not being hydrolyzed, has a penetrating power much inferior to gaseous chlorine and HTH, also inferior to Halazone and dichloramine, and that it is comparable to monochloramine.

These five points are of great interest when they are analyzed with some of the data, both published and unpublished, on cysticidal efficiency of these chlorine and chloramine compounds.

The activity of HOCl and inertness of OCl^- may be further confirmed by some of our unpublished data collected recently in a study of the cysticidal efficiency of HTH in tap water after a 10-min. contact and with and without acidification with citric acid. The results obtained at 28°C. are shown in Table 2.

TABLE 2

Cysticidal Efficiency of HTH in Tap Water

pH of the Chlorinated Water	Cysticidal Concentrations of HTH as Titratable Chlorine, ppm.		Estimated Amounts of HOCl and OCl^-, ppm.	
	Initial	Residual	HOCl*	OCl^-*
(1)	(2)	(3)	(4)	(5)
5.23	2.0	1.92	1.91	0.01
6.40	2.5	2.44	2.26	0.18
7.20	3.0	2.80	1.88	0.92
8.10	8.0	7.90	1.89	6.11
8.30	10.0	9.60	1.63	7.97
8.40	12.0	11.00	1.60	9.40
8.45	16.0	15.50	2.01	13.49
8.85	25.0	22.60	1.28	21.32
8.89	30.0	29.00	1.50	27.50
8.94	35.0	33.00	1.65	31.35
9.00	40.0	36.40	1.53	34.87

* The amounts of HOCl and OCl^- in columns 4 and 5 in the table were estimated from the dissociation constant of HOCl given by Skrabal and Berger (21).

The data presented in Table 2 undoubtedly confirm the statement made previously that the penetrating power of gaseous chlorine or hypochlorite solutions, under conditions where no unhydrolyzed Cl_2 exists, depends chiefly, if not entirely, on the amount of HOCl present. The OCl is inactive or non-cysticidal. The steady increase in the amount of titratable chlorine necessary to reach a cysticidal point when the pH was steadily increased seems just to maintain the amount of HOCl at a certain cysticidal level.

The slightly better cyst-penetrating power of Cl_2 over HOCl observed in the present study may also be supported by our data on cysticidal efficiency of gaseous chlorine and HTH. This was presented in a previous paper (20) in which the author reported that with short contact periods—15 and 30 min.—the gaseous chlorine showed a slightly better cysticidal efficiency in water at pH 7.0 than the HTH. In the light of the present study, this difference may be explained by the fact that, in water treated with gaseous chlorine, resulting in a final pH of about 7.0, some free chlorine (Cl_2) probably existed for a short time. The presence of this chlorine brought about a slightly quicker killing of cysts than the presence of HOCl alone when HTH was used.

The weaker cyst-penetrating power of chloramines observed here serves to explain our observations made previously (20) that chloramines with short contact periods—15 and 30 min.—are much less cysticidal than either gaseous chlorine or HTH. However, with long contact periods, such as 2 hr., chloramines were found just as cysticidal as chlorine and HTH (20), indicating that chloramines are probably much slower in their penetrating ability, but may reach the same efficiency as chlorine and HTH if sufficient time is allowed.

The fairly strong cyst-penetrating power of Halazone and the very weak cyst-penetrating power of succinchlorimide observed here also run parallel with the cysticidal efficiency of these two organic chloramine compounds found in the author's more recent studies. Some of these unpublished data are presented in Table 3 in order to show the relative cysticidal efficiency of these two organic chloramine compounds and also that of HTH.

TABLE 3

Relative Cysticidal Efficiency of HTH, Halazone, and Succinchlorimide

Kind of Compound Used	Contact Period—Min.	Temperature—°C.	pH of the Chlorinated Tap Water	Cysticidal Doses of Titratable Chlorine, ppm.	
				Initial	Residual
HTH[1]	10	23	6.4	3.0	2.9
Halazone[2]	10	23	6.6	12.8[4]	13.5
Succinchlorimide[3]	10	26	6.2	89.0	82.4

[1] HTH solution was used and the tap water was acidified with citric acid before dosing.

[2] Halazone tablets were used and the tap water was acidified with citric acid before dosing. The initial chlorine was estimated from the average amount of available chlorine from the tablet dissolved in distilled water.

[3] Succinchlorimide tablets were used. The water was not acidified but reached pH 5.0 after dosing. The initial chlorine was also estimated from the average amount of available chlorine from the tablet dissolved in distilled water.

[4] May be due to differences in the weight of Halazone tablets.

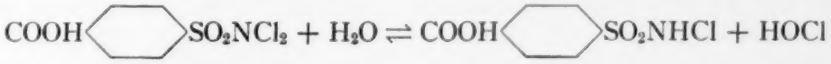
All these data indicate that the cyst-penetrating power of a chlorine or chloramine compound seems to run parallel with its cysticidal efficiency.

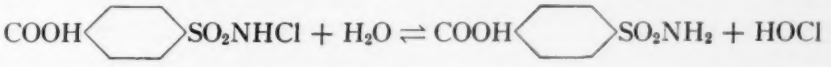
Probable Explanation of Differences in Cyst-Penetrating Power of Chloramine Compounds

In the last topic, it has been shown that free chlorine (Cl_2) has the best cyst-penetrating power, hypochlorous acid (HOCl) slightly less, and that hypochlorite (OCl^-) is apparently inert in its action. Dichloramine and Halazone seem to have about the same cyst-penetrating power, which is about $\frac{2}{3}$ that of gaseous chlorine and HTH. Succinchlorimide and monchloramine have the weakest penetrating power among these chlorine and chloramine compounds. In order to explain the differences in penetrating power of these chloramine compounds, a few tests were carried out to determine whether or not they hydrolyzed in water to form HOCl.

In examining the chemical formulas of these chloramine compounds, the reactions involving hydrolysis, illustrated below, were anticipated.

To determine whether hydrolysis took place and to determine the rate of hydrolysis, the methyl orange discoloration test was used. This test is based on the fact that HOCl bleaches the color of methyl orange solution. A quantitative determination of the HOCl formed by hydrolysis was made

1. 

2. 

3. $NHCl_2 + H_2O \rightleftharpoons NH_2Cl + HOCl$

4. $NH_2Cl + 2H_2O \rightleftharpoons NH_4OH + HOCl$

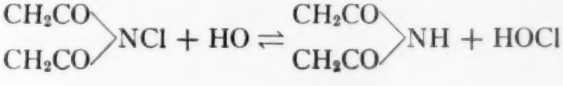
5. 

TABLE 4

Rate of Hydrolysis of Monochloramine, Dichloramine, Halazone, and Succinchlorimide in Distilled Water

Type of the Chloramine Compound	Concentration of Titratable Chlorine—*ppm.*	Temperature—°C.	Duration of the Solution—*min.*	Per Cent of Chlorine Hydrolyzed as HOCl
Monochloramine[1] (NH_2Cl)	25	25	15	0
			30	0
			60	0
			120	0
Dichloramine[2] ($NHCl_2$)	25	25	15	22
			30	22
			60	22
			120	22
Halazone[3]	25	25	15	32
			30	32
			60	32
			120	32
Succinchlorimide[4]	25	25	15	0
			30	0
			60	0
			120	0

[1] Chloramine solution at pH 4.5 (close to 100 per cent monochloramine).

[2] Chloramine solution at pH 8.5 (close to 100 per cent dichloramine).

[3] Tablets of Halazone were used, at pH 6.6.

[4] Tablets of Succinchlorimide were used, in a pH range of 4.0 to 8.0. There seemed to be a trace of hydrolysis at pH 8.0.

from the amount of methyl orange solution decolorized by reference to a chart which indicated the amount of HOCl. The chart was prepared with known amounts of HOCl. The results of tests made in this way are presented in Table 4.

From the above table, it is evident that while both monochloramine and succinchlorimide did not hydrolyze to a detectable amount even after a period of 2 hr., both dichloramine and Halazone hydrolyzed considerably even in a period of 15 min., forming a considerable amount of HOCl. From the per cent of chlorine hydrolyzed from Halazone, it seems that the hydrolysis of Halazone according to the second equation did not take place. These findings serve to explain why dichloramine and Halazone have fairly strong, and monochloramine and succinchlorimide have very weak cyst-penetrating power. The absence of hydrolysis in solutions of monochloramine and succinchlorimide and the presence of a small number of yellow-stained cysts in these solutions when high concentrations of titratable chlorine were used, together with the low cysticidal efficiency of monochloramine (20) and succinchlorimide (see Table 3), strongly indicate that these two chloramine compounds are capable of penetrating into cysts only if very large doses are used.

Action of Chlorine and Chloramine Compounds on Micro-Organisms

The result observed in this study that free chlorine (Cl_2) is just as cyst-penetrating as HOCl, if not slightly more so, clearly disproves the theory that chlorine compounds owe their germicidal power to the HOCl present in the solution. Buswell (22) thought that free chlorine probably played an important role in the process of destruction. He based his opinion on Jakowkin's statement that, in dilute solutions of gaseous chlorine, the hydrolysis is almost complete, but several hours are required before the equilibrium is reached, and he was also aware that, in ordinary practice and tests, short contact periods (15 to 30 min.) are needed to kill or destroy most of the bacteria. The fact that short contact periods are sufficient, together with the fact that the mono-

chloramine and succinchlorimide do not hydrolyze to form HOCl and yet are cyst-penetrating and cysticidal when large doses are used, clearly show that chlorine and chloramine compounds are capable of destroying micro-organisms without the formation of HOCl.

These facts, however, do not disprove the general belief that HOCl destroys micro-organisms by the release of nascent oxygen. In order to get some indirect evidence that the release of nascent oxygen from HOCl is not likely to be the process of destroying micro-organisms, some tests were made on cysts with H_2O_2 solutions. The results are shown in Table 5.

TABLE 5

Cysticidal Efficiency of H_2O_2 in Distilled Water at pH 6.1 and 25°C.

Contact Period— *Min.*	Concentrations of H_2O_2— *Ppm.*	Cultural Results of the Treated Cysts
15	3,000	Positive
30	3,000	Positive
60	3,000	Positive
120	6,000	Negative

It is shown in the table that, even with a concentration of H_2O_2 up to 3,000 ppm. and a contact period of 60 min., cysts were not all killed. This concentration of H_2O_2 would yield an amount of nascent oxygen more than 1,500 times that which would be supplied by a cysticidal dose of HOCl. This observation suffices to show that oxidation by nascent oxygen liberated by the HOCl is very unlikely to be the important means of destruction. It is probably a process of oxidation by chlorination.

Furthermore, it was thought that if the HOCl acted on the protoplasm of the organism by the nascent oxygen, it would result in an increase in the HCl concentration, and detectable pH changes should be recorded if a sufficient amount of HOCl was allowed to act on some protein substance. Tests were, therefore, made by treating an 0.05 per cent proteose-peptone solution with varying amounts of HOCl (prepared from HTH) and recording the pH changes. The results are presented in Table 6.

TABLE 6

Some Chemical and Physical Changes Which Occurred in a 0.05 per cent Proteose-Peptone Solution Dosed with Varying Amounts of HOCl (as HTH) for a Contact Period of 4 Hr.

Initial Chlorine *Ppm.*	Residual Chlorine *Ppm.*	pH of HOCl Soln.	pH of Proteose-Peptone Soln.	Final pH of Chlorinated Peptone Soln.	Turbidity* of Chlorinated Peptone Soln. *Ppm.*
500	173	4.5	4.5	4.0	84
300	123	4.5	4.5	4.1	29
100	26.4	4.5	4.5	4.2	12.5
50	17.3	4.5	4.5	4.4	9.4
30	6.7	4.5	4.5	4.5	8.7
10	0.5	4.5	4.5	4.5	8.3
5	0.0	4.5	4.5	4.5	7.6
0	0.0	—	4.5	4.5	6.8

* The amount of precipitation of proteose-peptone was determined by means of an electro-photelometer and expressed as turbidity in ppm.

In the table it is shown that only a slight lowering of pH value was noticed in the three highest concentrations of HOCl used. It was estimated that if the HOCl decomposed to form HCl and nascent oxygen, 500 ppm. of initial chlorine, resulting in 137 ppm. residual chlorine, should have produced a 0.0092 *N* HCl and a pH close to 2.0. Since the protein might have some buffering effect on the H-ion concentration, a control test was made by adding HCl to the 0.05 per cent proteose-peptone solution in sufficient

amount to give a normality of 0.0092. The final pH turned out to be 2.6. This apparently shows that if HOCl ever decomposed in this fashion, it occurred only to about 4 per cent of the total HOCl reduced and when a very large dose of HOCl was used.

Most Probable Cause of Death of Cysts Exposed to Chlorine or Chloramine Compounds

Having shown that chlorine and chloramine compounds penetrate into the cysts, that the cyst-penetrating power of these chlorine and chloramine compounds runs parallel with their cysticidal efficiency, and that these compounds exert their cysticidal action chiefly by virtue of the active chlorine and not by the nascent oxygen liberated by HOCl, it was finally attempted to determine the cause of death of cysts exposed to chlorine or chloramine compounds. Were the treated cysts rapidly destroyed by the penetrated chlorine, or did the chlorine combine with the protein substance in the protoplasm of the cysts to form an organic chloramine compound which poisons the cysts?

It was thought that if destructive changes sufficient to account for the death of cysts could be demonstrated in cysts exposed to a minimal cysticidal dose of chlorine, one might be reasonably sure that the exposed cysts were destroyed directly by the penetrating chlorine. In Table 6, it has been shown that when chlorine was dosed into a 0.05 per cent solution of proteose-peptone, precipitation took place. In this table, it is noticed that, even with an initial chlorine of 5 ppm., some precipitation occurred and more so with higher concentrations of chlorine. This precipitation must have been associated with certain chemical changes between the chlorine and the proteose-peptone, since there was a proportional amount of chlorine reduced to chloride along with the precipitation.

In previous studies on cysticidal efficiency of gaseous chlorine, HTH, and chloramines (19, 20) and in recent studies on HTH, Halazone and succinchlorimide (unpublished data), the writer has repeatedly observed that when a minimal cysticidal dose of titratable chlorine was reached, all cysts showed a finely divided granular appearance, many cysts showed visible nuclei, and a few cysts showed a slight shrinkage of the cytoplasm, leaving a very narrow space between the cytoplasm and the cyst wall. When larger doses were used, all cysts showed coarsely granular appearance and visible nuclear structure. When very large doses were used, cysts appeared spongy or honeycombed in appearance and many cysts had a shrunken protoplasm, leaving an empty space inside the cyst. These physical changes certainly indicate that some sort of cytological changes had taken place in the cysts and that the death of the cysts was probably associated with these changes. In order to find out what sort of cytological changes might have taken place as a result of the action of the penetrating chlorine, tests were made on cysts with gaseous chlorine, chloramines and succinchlorimide. With gaseous chlorine, doses ranging from the minimal cysticidal to several times the minimal cysticidal were used. With chloramines and succinchlorimide, only the minimal cysticidal dose was used. The minimal cysticidal dose was determined by culturing some of the treated cysts, while the other cysts were stained by the iron-hematoxylin method. The results observed are described as follows:

1. When a minimal cysticidal dose of chlorine was used, the cyst wall of the treated cysts took the hematoxylin stain more deeply than that of the untreated cysts, indicating definite changes. The cytoplasm of most cysts was coarsely granular and stained deeply, appearing spongy in a few cases, which would indicate that coagulation and other changes had taken place in the cytoplasm. The nuclei of most cysts were vague in outline and took a lighter stain than those of the untreated. In many cysts, the nuclear membrane and the chromatin material underneath it were irregular or beading in appearance. In a few cysts, cracking of the nuclear membrane and the chromatin material and fading of the karyosome were noticed.

2. When double the minimal cysticidal dose of chlorine was used, only a small number of cysts appeared as described in 1, while the majority of them showed a spongy or honeycombed cytoplasm. In some cysts, rather markedly shrunken protoplasm was noticed, leaving apparent empty spaces inside the cysts. In most of the cysts, the nuclei were severely damaged, being very irregular in outline, and a small or a large part of the nuclear membrane and the chromatin material was missing and disappearance of the karyosome was noticed. In some cysts, only small dark masses were noticed in the shrunken cytoplasm, suggesting nuclear structure.

3. When the dose was three times the minimal cysticidal, changes described in 1 were not observed, and those in 2 were noticed in a small number of cysts. In a majority of the cysts, the cytoplasm was found shrunken into a small dense mass, leaving an empty space between the mass and cyst wall. Scattered, dark-stained spots were noticeable, suggesting remnants of nuclear material.

The changes described above are illustrated in the accompanying plate.

From these results, it is apparent that even in cysts treated with the minimal cysticidal dose of chlorine as gaseous chlorine, chloramines, or succinchlorimide, there were definite cytological changes associated with the death of the cysts. The changes described in 1 suggest a partial coagulation of the cytoplasm and some damage to the nuclear structure. While such damage would affect the nuclear division, resulting in the death of the cyst, the immediate cause of death seems to be the physical and chemical changes in the cytoplasm. Since the viability of a cyst depends upon the ability of the cytoplasm to carry on metabolic activity, upon ability to penetrate the cyst wall (probably by secreting enzymes to digest a small part of the wall), and upon the mobility of the cytoplasm to enable the metacystic ameba to emerge from the cyst, the coagulation of the proteins in the cytoplasm would result in stiffness of the cytoplasm. Associated with the coagulation, there were probably chemical changes which resulted in destruction of enzymic as well as other physiological activities.

While these structural changes strongly indicate that a destructive process results from oxidation by the active chlorine, there has been indirect evidence that some of the chlorine might combine with certain amino-acids to form organic chloramine. In the previous tests dealing with the effect of proteose-peptone on the cysticidal efficiency of gaseous chlorine (19), the writer found that, even when a dose of 2.5 ppm. of chlorine was added to a 0.02 per cent proteose-pep-

tone solution, with a contact of 1 hr., about 5–10 per cent of the chlorine persisted as residual, indicating that while most of the chlorine was reduced by the protein to chlorides, a small amount combined with it to form organic chloramine. Wright (23) found that amino-acids such as cystine completely removed the residual chlorine in a 5-hr. contact period, while others like glycine failed to take up any residual chlorine when 140 ppm. of chlorine as hypochlorite were used, suggesting that certain types of amino-acids more readily reduce the chlorine in the chlorinating agent to chloride, while other types more readily form chloramine with it. It is the writer's feeling that in the process of chlorination of cysts both these reactions probably take place when the penetrating chlorine is in contact with the protoplasm. However, the destructive changes as described before occur so fast that they render the cysts nonviable before the newly formed chloramine has a chance to poison the cysts.

While these observations made on cysts of *E. histolytica* may be applicable to micro-organisms in general, there is some evidence that certain chlorinating agents may have destructive action on specific kinds of bacteria. For example, as already pointed out, succinchlorimide was found far inferior to gaseous chlorine and HTH in its cyst-penetrating power and cysticidal efficiency, and also inferior to Halazone and dichloramine under similar conditions. However, in recent tests made on *Esch. coli, Sh. dysenteriae,* and *Eb. typhi* (unpublished data), succinchlorimide was found just as strongly bactericidal as HTH and more so than Halazone. It was also less affected by the presence of organic material than either HTH or Halazone. Results of tests that were made suggested that succinchlorimide is not bacteriostatic but reacts with, or penetrates into the bacteria body very quickly when the two are brought together. While it is difficult to discuss its mode of action on these intestinal bacteria without further information, the results obtained seem to indicate that its action on the bacteria named does not depend on the amount of active chlorine (Cl_2 and HOCl), as was the case with cysts.

Summary and Conclusion

1. A study has been made on the mechanism of destruction of cysts of *E. histolytica* by chlorine and chloramine compounds in water.

2. It was found that when cysts were exposed to solutions of gaseous chlorine, HTH, dichloramine, monochloramine, Halazone and succinchlorimide, there was penetration of chlorine into the cysts.

The cyst-penetrating powers of these compounds are shown below in order of their activity:

Cl_2
HOCl
Halazone
Dichloramine
Succinchlorimide and Monochloramine

The greater the concentration of titratable chlorine, and the longer the contact period, the greater was the penetration of chlorine into the cysts.

The effect of pH on the cyst-penetrating power of gaseous chlorine and HTH was due to the formation of Cl_2, HOCl, and OCl^-. (Below pH 2.0 a significant amount of Cl_2 is formed. Between pH 2.0 and 5.0, most of the

chlorine exists as HOCl. At pH above 8.5, a very small amount of HOCl is formed and most of the chlorine exists as OCl^-.)

The pH effect on chloramines was through the formation of di- and monochloramine. The effect of pH on Halazone seemed to be on the hydrolysis product—HOCl. The effect of pH on succinchlorimide was not significant.

The good cyst-penetrating power of both Halazone and dichloramine was attributed to the hydrolysis product—HOCl. Succinchlorimide and monochloramine were not found to be hydrolyzed.

3. The cyst-penetrating power of these chlorinating agents was found to run parallel with their cysticidal efficiency.

4. Hypochlorite (OCl^-) was found non-cyst-penetrating and non-cysticidal.

5. The action of chlorine and chloramine compounds on cysts was attributed to the active chlorine which may oxidize or chlorinate the proteins in the protoplasm. The possibility of action by nascent oxygen liberated by HOCl was indirectly studied, and the evidence strongly indicated that this was unlikely to occur.

6. The cause of death was also studied. It was found that definite destructive changes occurred in cysts exposed to a minimal cysticidal dose of chlorine. From indirect evidence, the writer believes that although both oxidation of the proteins in the protoplasm and chlorination of the proteins to form chloramine may occur when the penetrating chlorine is in contact with the protoplasm, the destructive changes taking place probably render the cyst non-viable long before the newly formed chloramine has a chance to poison the cyst.

7. While these observations made on cysts may be applicable to the destruction of micro-organisms in general, recent data indicate that in the destruction of bacteria by chloramine compounds, such as succinchlorimide, a destructive action takes place that is more specific than the general principles here described.

Acknowledgments

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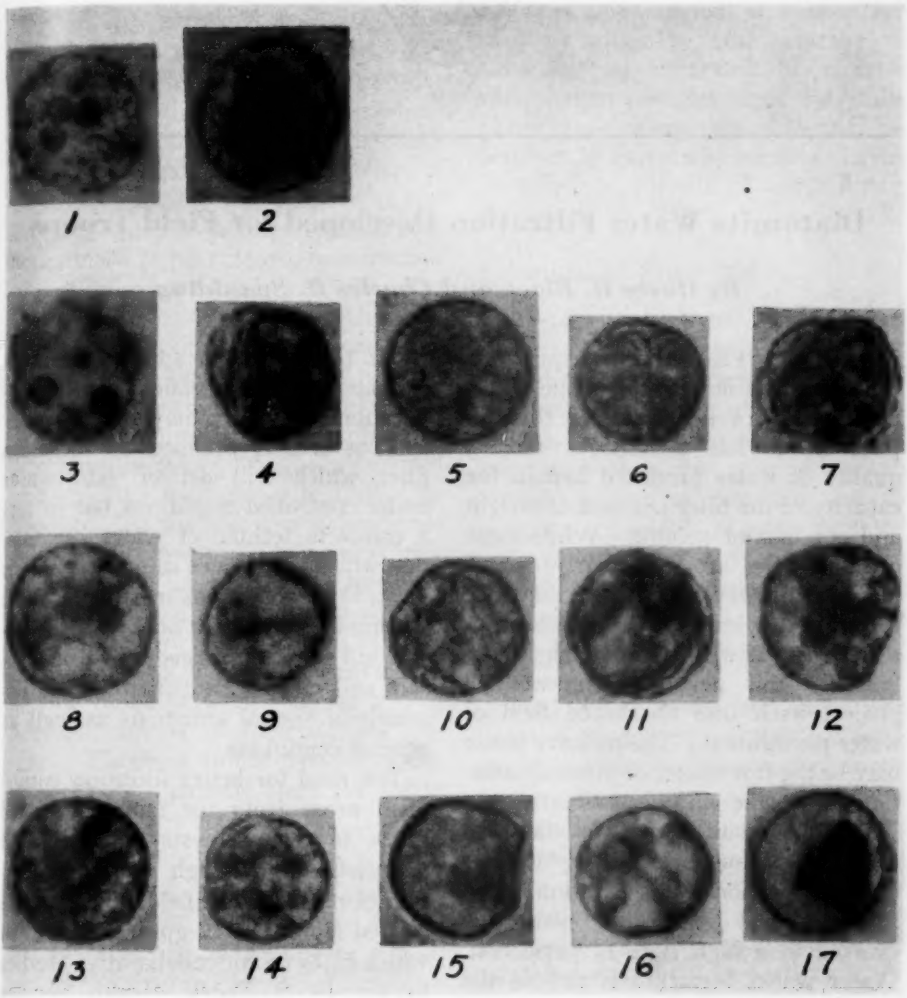
Description of Plate

FIGURES 1—17

All figures in the plate were photographs taken with a microcamera (magnification 1000 times in diameter). These photographs were projected on enlargement paper (magnification 2 times in diameter).

FIGS. 1 AND 2. Typical normal quadrinuclear cysts of *Endameba histolytica* before chlorine treatment. One of the nuclei in each cyst is out of focus. The cyst in Fig. 2 has chromatoid material (also out of focus). The nuclei are deeply stained, clear and smooth in outline and have distinct karyosomes. The cyst wall and cytoplasm are lightly stained and the latter has a finely granular appearance.

FIGS. 3, 4, 5, 6 AND 7. Typical changes in cysts treated with a minimal cysticidal dose of chlorine. The cyst in Fig. 3 shows no significant changes of the nuclei, except that the outline of the nuclei is not as sharp as that of the nuclei of normal cysts. The cytoplasm in this cyst is more deeply stained and is rather spongy in appearance. Part of the nuclear membrane of the cyst in Fig. 4 and the chromatin material underneath it have disappeared and the cytoplasm has become spongy. Cysts in Figs. 5, 6 and 7 show coarsely granular cytoplasm and lightly stained nuclei, the nuclei being vague and irregular in outline. The nuclei of cysts in Figs. 5 and 6 show marked cracking or disappearance of part of the nuclear membrane and the chromatin material underneath it. Splitting or fading of the karyosome can be



observed in some of the nuclei. The nuclei of the cyst in Fig. 7 are so altered that structures can not be definitely identified. The cyst walls in all figures (except Fig. 3, in which the cyst wall is out of focus) are stained more deeply than those of normal cysts.

FIGS. 8, 9, 10, 11 AND 12. Typical changes in cysts treated with double the minimal cysticidal dose of chlorine. The cytoplasm has a honeycombed appearance in all cysts. Large empty spaces are found in the cysts in Figs. 9 and 12. In these cysts the nuclei are vague and irregular in outline and the nuclear membrane and chromatin material underneath it appear cracked in many places. The karyosome in most of the nuclei is fading.

FIGS. 13, 14, 15, 16 AND 17. Typical changes in cysts treated with triple the minimal cysticidal dose of chlorine. The cytoplasm of the cysts in Figs. 13 and 14 is honeycombed in appearance. Dark masses in the deeply stained cytoplasm suggest nuclear structure. The cytoplasm of cysts in Figs. 15, 16 and 17 has shrunk into a dense mass, leaving a large empty space between the cystoplasm and the cyst wall. Deeply stained small masses are noticeable in the shrunken cytoplasm, suggesting remnants of nuclear structure.

Diatomite Water Filtration Developed for Field Troops

By Hayse H. Black and Charles H. Spaulding

DIATOMITE filtration equipment has been developed by the Engineer Board for field use. In this application it has advantages in the quality of water produced and in the capacity of the filter per unit of weight and per unit of volume. While these characteristics are particularly desirable for military equipment they are certainly not undesirable in other applications. It will be interesting to see how far this new development will project itself into the broad field of water purification. The military phase may be the forerunner of other applications in a wide variety of situations.

It is not assumed that the diatomite method will immediately displace existing conventional sand filtration. The modern rapid sand filter plant has evolved to a high state of perfection. Water works literature is rich in the lore of the art. In contrast with this record, the dearth of information on the new method is appalling. Only such pressing needs as arise from logistics could justify turning radically from past experience to a method with no background of acceptance in water works practice. The authors have appreciated the implications and complications of such a move. The problem has been to produce not merely a filter which will deliver safe water under controlled conditions but in fact a complete technic of water purification which will assure safe water under any and all conditions met in the field. We are concerned not only with the device but with the procedure to make it safe and efficient, anticipating the demands of special situations as well as general conditions.

The need for better filtration equipment arose from the failure of sand filters to remove cysts of *Endameba histolytica* at the high rates of filtration employed in the field. These rates ranged from 6 to 12 gpm. per sq.ft. at which rates recent collaborative studies by the U. S. Public Health Service with the Engineer Board showed many cysts passing the filters. On the other hand, diatomite filtration was found to affect virtually complete removal of cysts under most severe tests. Other investigations, as for example those by Chang and Fair (1), have shown the high resistance of cysts to chlorination and the interference of pH. In view of these facts, development of diatomite filtration field service has been pressed as rapidly as possible.

A paper presented at the Milwaukee Conference on June 14, 1944, by Capt. Hayse H. Black, C.E., Chief, and Charles H. Spaulding, Engr., C.E., of Water Supply Equipment Branch, The Engineer Board, Fort Belvoir, Va.

General

Diatomite, sometimes called diatomaceous silica, kieselguhr or diatomaceous earth, consists of the skeletal remains of diatoms found in abundant geological deposits in a number of localities, notably in California and Oregon, but elsewhere as well. Those accustomed to microscopic examination of surface water easily recognize the typical cylinders, discs, frustules and other forms contained in the conglomerate mass of diatom capsules most of which are more or less fragmented. The filter-aid used in water purification is diatomite which has been selected and calcined with or without flux to produce the desired flow characteristics. In dry form as packaged it may weigh 8 to 11 lb. per cu.ft. After wetting the volume shrinks to an equivalent density twice these figures.

The fineness of particles varies over a wide range between samples and in a single sample of filter-aid, for example, Elsenbast and Morris (2) show the following particle sizes for Celite 503 and Filter-Cel:

Particle Size Microns	*Celite 503 Per cent*	*Filter-Cel Per cent*
>40	12.0	2.5
40—20	25.5	8.0
20—10	33.5	14.0
10— 6	22.0	19.0
6— 2	21.5	37.5
<2	1.5	19.0

The shape of the particles also affects the flow characteristics of the material as shown by Cummins (3). This appears to be another aspect of size. The larger sizes are discs and boat-shaped particles. Smaller sizes are spicules and fragments.

Chemically, diatomite is silica with variable small percentages of clay, sand and earthy impurities. In calcining, a small amount of alkaline flux may be added by which means the fines are agglomerated or clumped with larger particles, thus increasing porosity. The reaction of the finished product is essentially neutral, having no effect on the pH of water filtered through it.

Selection of Filter-Aid

As previously stated, filter-aid particle sizes cover a wide range. The size of particles, moreover, determines the flow rate under a given set of conditions. Therefore it has been necessary to explore the relation between various grades of filter-aid and the quantity and quality of water produced with these grades. At first this appeared to be a complex problem in view of many other variables involved. Actually the problem has not been difficult.

The first experimental runs were made on the assumption that raw water might be filtered without pre-treatment Under such an assumption it was necessary to select a filter-aid primarily on the basis of clarity of water produced. Working at room temperature with raw water having low natural turbidities reinforced with clay and/or activated carbon, it was possible to deliver clear water with one of the slower filter-aids. Later when the same filter-aid was used with cold water of moderately high turbidity (70 ppm. or more) the results were erratic, and filtered water turbidities of several parts per million were common. This led to tests of other filter-aids, variations in rate of filtration and eventually to pre-treatment of raw water as a means of obtaining uniformly satisfactory results. Filter-aids which had been specially treated or mixed with

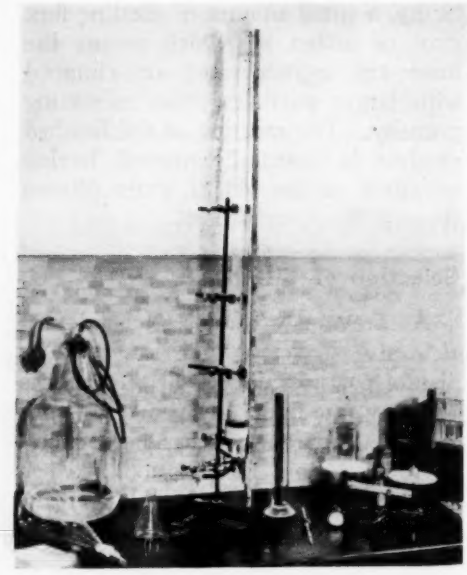


FIG. 1. Apparatus for Flow Test of Filter-Aids

TABLE 1

Flow Test of Filter-Aids

Apparatus

1 Filter tube, glass, 2-in. od., 1.88-in. id., 48 in. long
1 Funnel, Buechner, 2½-in. diameter
1 Pinchcock
1 Gasket, rubber for joint between tube and funnel
1 Separatory funnel, pear shaped, 1000-ml. capacity
1 Stopwatch
1 Thermometer
1 250-ml. graduate
1 Ring stand with clamps
Filter paper, qualitative, semi-crimped, No. 9-795, 55 mm.
Rubber tubing, ¾ in.
Glass wool

TABLE 1—*Continued*

Assembly

1.—Clamp glass tube in large ring stand.
2.—Cement gasket to lower end of glass tube leaving ¼-in. overhang.
3.—Place 2 pieces of filter paper in Buechner funnel.
4.—Slip Buechner funnel over gasket and clamp into place.
5.—Attach short piece of hose with pinchcock to the stem of the Buechner funnel, bottom end of hose 5 in. below filter paper.

Procedure

1.—Weigh out 50 g. of filter-aid sample.
2.—Mix with 350 ml. distilled water in 600-ml. beaker.
3.—Pour slurry in separatory funnel and immediately deliver into filter tube directing flow down the side of the tube so as not to break filter paper.
4.—Rinse beaker with 150 ml. distilled water, pour into separatory funnel, rinse, then deliver to glass filter.
5.—Open pinchcock and allow water to drain off until ¼ in. of water remains on top of filter cake.
6.—Place piece of glass wool on top of filter cake, sufficient to cover cake and prevent diffusion into water to be added.
7.—Fill glass tube to 47-in. level with distilled water; while filling leave pinchcock open. Glass tube measurements begin at filter paper.
8.—When water reaches 46-in. level, use stopwatch to time number of seconds to collect 250 ml. water.
9.—Record temperature of distilled water, correct rate of flow to 70°F. by using the formula $N_{70}/N_t \times R_t = R_{70}$.
N_t is the viscosity of water at the temperature of the test, N_{70} is the viscosity at 70°F., R_t is the time required at temperature t and R_{70} is the time required at 70°F.
10.—Divide 250 by number of seconds required to obtain rate in ml. per second.

alum showed some promise as a medium for raw water filtration but this departure is not logical for field use in view of the wide variation in coagulant demand to be anticipated. Control of rates of filtration had no beneficial effect on water clarity, a rate of 1 gpm. per sq.ft. showing no improvement over a rate five times as fast. On the other hand, pre-coagulation and settling were effective. With coagulation it was found that any of the filter-aids with one exception, the fastest filter-aid, produced clear water under all condi-

tions. The next fastest filter-aid was therefore the logical selection with others acceptable in the order of speed.

For a comparison of flow rates of filter-aid it has been necessary to devise a method of measuring the resistance to flow under a set of arbitrary and uniform conditions. The methods used by the filter-aid industry heretofore seemed inapplicable even though logical in the field of industrial liquids for which they were devised. The method adopted is described under "Flow Test of Filter-Aids" (Table I) and the apparatus is shown in Fig. 1. Using this test a wide divergence in flow rates of various filter-aids is noted as shown in Table II. The purpose of the test is primarily to identify the filter-aid by its flow characteristics. It will be seen that the highest rate in the table is ten times the lowest rate, while others fall at various intervals between. The range which has been found most useful lies between 0.6 ml. per sec. and 1.5 ml. per sec., under the test conditions—a wide zone, permitting at least two grades of filter-aid to be considered. The highest flow rates found, ranging from 1.56 to 2.28, did not produce satisfactory clarity when conditions were adverse.

TABLE II

Identification of Filter-Aids

Type Filter-Aid 50-mg. Sample	*Rate of flow of distilled water at 70° F. through test Filter-Aid—ml./sec.*
Untreated Filter-Aids	
545	1.56–2.28
D-4200	1.00–1.47
535	0.62–0.81
Mollicel	0.37–0.40
Speed plus	0.34–0.37
D-40	0.24–0.25
Hyflo	0.23–0.24
Alum Treated Filter-Aids	
236-V	0.89–1.09
234-V	0.66–0.78
228-V	0.62–0.75
235-V	0.46–0.51
Sorbocel	0.21–0.22

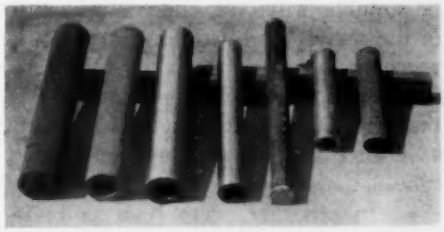


FIG. 2. Various Types of Filter Elements

Filter Septum

Diatomite as a filter medium requires a supporting base or septum, sufficiently rigid against flexure, permeable to permit maximum flow rates without significant loss of head, but fine enough to support the filter cake. For this purpose, cylindrical elements of porous refractory materials and helically wound wire have been found most adaptable. Upon such an element a pre-coat cake of diatomite is deposited by circulating slurry through the unit. The water may be recirculated to effect complete removal of suspended particles or it may be wasted until it flows clear from the accumulated filter cake, which can happen in less than one minute under proper conditions. The cake when deposited will be .06 in. to .09 in. thick if a conventional dose of 1 to 1½ lb. of filter-aid per 10 sq.ft. of septum is used. This cake is the filter medium through which the water passes and upon which suspended matter is deposited.

The selection of the filter septum is especially important under field conditions. A number of materials would

be suitable providing one could be sure of the service and handling they would receive. Various types of filter elements are shown in Fig. 2. Any of these filter elements can be used with assurance that it will support a filter cake satisfactorily. They differ, however, in other respects such as resistance to flow, weight, durability, response to backwash, and liability to plugging. It is likely that several of these types will find wide application even though they may fail to meet military requirements.

Several forms of the filter septum have been proposed by manufacturers and others. In general the cylindrical form has been most promising, partly because of the inherent strength of the cylinder and the hydraulic flow characteristics. The capacity can be determined by the number of elements used and by their diameter and length. The elements must be spaced so as to permit flow of water around and between them after the pre-coat cake has formed and allowing for accumulation of the body feed. A clearance of 1 in. between elements should permit accumulation of 0.8 lb. of filter-aid per sq.ft. without allowance for suspended matter removed from the water.

Filter Shell

To construct a diatomite filter it is necessary only to enclose in a filter shell one or more septum elements connected to a common header and provide inlet and outlet connections. There are a number of features, however, incorporated to promote the proper functioning of the equipment.

The design of the filter shell must be such that the filter-aid which enters with the applied water will be kept in suspension until deposited on the filter element as cake. It is further required that velocities of incoming water shall not be directed so as to scour the filter cake, thus removing it from the septum at one point and depositing at another. A third requirement is that the arrangement permit quick and complete removal of filter cake from the shell during backwash. In all of these respects a conical bottom is suitable for entrance of applied water and outlet of wash water. Above this cone the filter elements are suspended from a manifold head bolted to the cylindrical shell. The assembly should be reasonably accessible so that it can be opened for occasional inspection, removal or cleaning of elements.

Backwashing

Another important feature of a diatomite filter is provision for backwashing. Under most favorable conditions of applied water, filter runs may be comparable in length to those of rapid sand filters. Under other less favorable conditions the runs may last less than 30 min. partly due to the limitations of storage in the field. The success or failure of the diatomite method under such conditions would hinge on the economy of time and water used for backwashing. Fortunately it has been possible to develop a backwash technic which reduces the time required to 30 sec. and the filtering cycle can be resumed within 1 min. The quantity of water required may be approximately 5 gal. per sq.ft. and maximum percentage, assuming 15 min. runs, about 7 per cent. The wash water should average 2 per cent or less.

The method of backwashing adopted consists of reversing the flow of water through the filter by a valve to the suction side of the pump. The pump discharge is diverted to waste during the backwash. The filter effluent hose

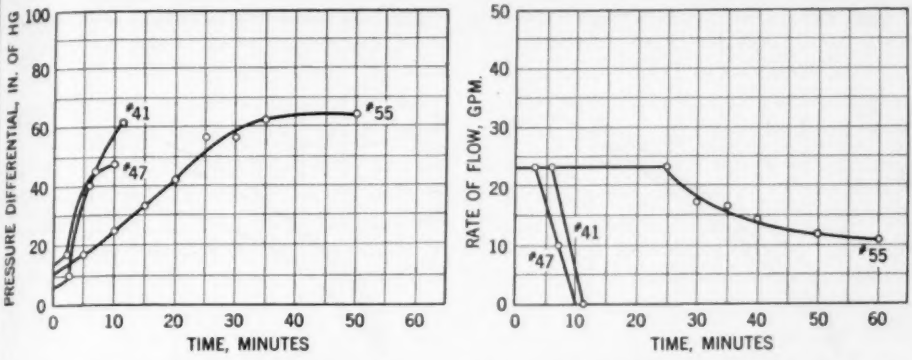


FIG. 3. Tests Showing Effects of Pre-coat Thickness and Necessity of Body Feed

Tests Were Made With a Converted Portable Unit, 3 Aloxite Elements, 6.7-Sq.Ft. Area, Gorman-Rupp Pump Model 5210 W, Potomac River Water

Run No.	41	47	55
Temp., °F.	50	46	50
Raw Turb., ppm.	44	33	43
Filter Turb., ppm.	0.4	0.3	0.1
Filter-Aid	Sorbocel	Sorbocel	Sorbocel
Body Feed, lb.	0	0	2
Pre-coat, lb.	1	2	1

is submerged in the filtered water storage tank where it acts as suction intake. The backwash ends with the filter shell full of filtered water ready for the pre-coat slurry. There has been no change of valves on the effluent side of the filter end and no connection around the filter by which raw water might find its way to the filtered water storage. Other methods of backwashing have been proposed but the method described seems simplest, safest and adequate.

Body Feeder

An important accessory to a diatomite filter is the so-called body feeder by which filter-aid is added during the filtering cycle. The purpose of body feed as distinguished from pre-coat is to retard the increase in loss of head which, as in any filter, begins relatively low and rises as the removed solids accumulate. The accumulation of such solids as a slime at the surface of the pre-coat cake would frequently result in a very short filter run, perhaps only 5 or 10 min. long. By the addition of filter-aid slurry during filtration the cake surface grows radially and the porosity is maintained for a longer period. There are times when no body feed is required to produce filter cycles lasting several hours. The usual condition, however, is represented by Figure 3 in which the delivery of water with body feed in run No. 55 is compared with two runs, No. 41 and No. 47, without body feed under nearly identical conditions. Runs No. 41 and No. 47 were over in about 10 min. while No. 55 could have continued for more than an hour. The importance of body feed is apparent. An increase of pre-coat in No. 47 decreased the yield as compared to No. 41. Com-

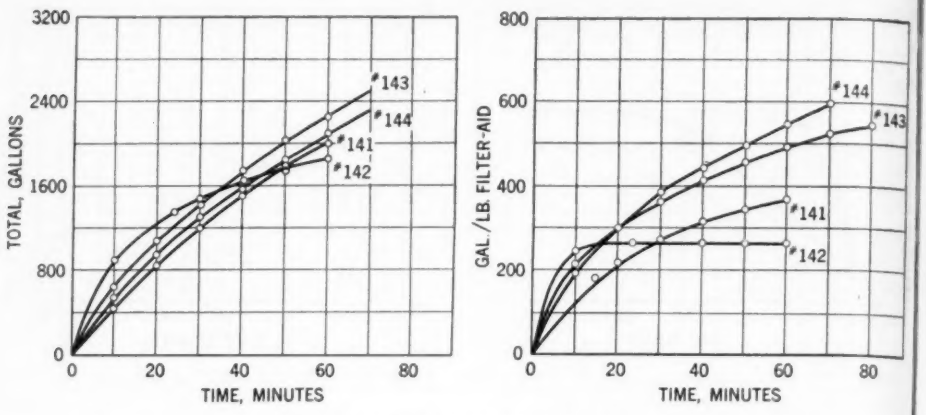


FIG. 4. Tests Showing the Effects of Varying the Quantity of Body Feed

Tests Were Made With a Converted Portable Unit, 7 Aloxite Elements, 15.5-Sq.Ft. Areas, Jaeger 2APS Pump, Dilution Body Feed Rate Program No. 2 503-Filter-Aid, Potomac River Water Coagulated and Settled

Run No.	141	142	143	144
Body Feed, lb.	4	6	3	2

plete coverage of the elements is apparently the sole requirement as to precoat thickness.

The quantity of body feed required depends on the character and amount of suspended solids but no simple method of determination is available for field use nor is such a method likely to be developed. Generally speaking, it depends upon the quality and quantity of suspended solids with emphasis on the quality. Organic slimes in small amounts will certainly seal filter cake more rapidly than granular inorganic material even though the latter is relatively fine. Diatomite itself is a fine material which when suspended in water imparts turbidity proportionate to the amount used; yet diatomite is a filter-aid. The method of determining the optimum quantities of filter-aid to use in any case is purely empirical. It consists of a series of filter cycles using various quantities of filter-aid and comparing the results. Such a comparison is shown in Fig. 4. In this comparison a 3-lb. batch of filter-aid produced the best yield. The 4-lb. batch was inferior and the 6-lb. batch the poorest in yield. The 2-lb. batch was most economical in gallons per pound of filter-aid.

Because the required dosage of filter-aid is indeterminate in advance, the reverse procedure of proportioning the water to the filter-aid has been adopted. An arbitrary initial charge of filter-aid is placed in the slurry feeder and the contents are displaced by constant dilution from an orifice box. This starts each cycle with a generous application of filter-aid which is diluted as the run proceeds. If the water is easy to filter the pumpage rate will decrease slower than the concentration of the slurry. If the water is difficult to filter the rate will decrease faster than the concentration of the slurry and the run will end with a considerable quantity of unused filter-aid. In each succeeding

cycle the same charge of filter-aid will be added and the concentration of filter-aid will be increased by the amount of filter-aid remaining from the previous run which will be a large quantity in the case of a short run and an insignificant quantity in the case of a long run. Thus the slurry feed builds up automatically for difficult filtering and the length of run is the ultimate limit of economy.

There are a number of practical reasons why this method of feeding slurry is advantageous: (1) The rate of pumpage is high at the start and gradually diminishes. This calls for larger quantities of filter-aid at the beginning. (2) The pre-coat quantity is an initial investment justifying generous application of body feed at the start. As the run proceeds this investment is absorbed and amortized by the water delivered, each succeeding gallon having less significance. (3) The method tends to starve the filter at the end of a cycle, thus avoiding extravagant use of filter-aid. Many cycles are arbitrarily short due to the limitations of storage and transport. (4) It provides a solution for a difficult problem of measuring small quantities of filter-aid either dry or in suspension.

Pre-treatment

Reference has been made to the use of pre-coagulation and settling. As practiced in the tests this is carried out in 3,000-gal. canvas tanks 47 in. high and 135 in. in diameter. The required coagulants are introduced into the water by suspending the dry chemicals in a screen bucket in the turbulence produced by raw water entering the tank. The raw water hose is hung over the side of the tank and the stream of water directed tangentially so as to produce rotation of the tank contents. Filling requires 12–24 min. depending on whether one or two pumps are used. It has been found that best results are obtained with rapid filling which promotes vigorous agitation and improves coagulation. When filling is complete the coagulant screen is removed and the water comes to rest in 15–30 min. This batch treatment produces excellent results particularly after some sludge has accumulated from previous fillings. Most of the floc has settled by the time the currents have subsided. Results improve naturally with longer settling thus utilizing delays in filtration which may be expected in the operation of such systems with limited storage.

In many runs activated carbon and calcium hypochlorite have been used in conjunction with coagulation in order to establish the practicability of complete treatment by the batch method. The coagulant used is ammonium alum which has been standard government issue for field troops for some years. It furnishes more than enough ammonia for the formation of monochloramine and assures a long lasting residual chlorine. With this coagulant, chlorine residual is not materially affected by activated carbon in the quantities used. Residual chlorine is easily maintained at 1 ppm.

For several months the treatment at the experimental station on river water has been:

Alum	2–5 gpg.
Hypochlorite	4 ppm. (equal to 2.8 ppm. Cl)
Activated Carbon	10 ppm.

More recently the dose of activated carbon has been raised to 20 ppm. to meet summer conditions. This treatment has resulted in production of most palatable water free from chlo-

rinous taste but with uniform residual chlorine of 1 ppm. plus or minus 25 per cent. It is believed that the introduction of the chlorine in advance of filtration adds materially to the safety of the procedure.

Effect of Pre-treatment on Quality of Filtered Water

Bacterial samples were collected during 63 filter cycles of which 32 were unsettled water and 31 were coagulated and settled prior to filtration. It was the purpose of this sampling to show the quality of filtered water likely to be obtained in routine operation during which attention would be directed normally to yield and clarity. Samples of raw water were also collected sufficient to indicate the range of total counts, both 37°C. and 20°C., as well as the *Esch. coli*. Of the filtered samples no quantities less than 10 ml. were planted in fermentation tubes. All presumptive positives were confirmed in brilliant green bile broth (Tables III, IV, V).

The evidence shows clearly that coagulated and settled water when filtered may be expected to approximate U.S. Public Health Service standards without chlorination in this location. Only one sample of filtered water was definitely unsatisfactory. An examination of the other data pertaining to the unsatisfactory filter cycle shows unusually poor coagulation in the pre-treatment and the use of the coarsest filter-aid available. This filter-aid is the only one which has occasionally produced turbid filtered water after pre-treatment and is not recommended for the purpose, although when other conditions are normal it is satisfactory. The remaining positives are well scattered and amount to but one per fifteen tubes planted. It should be noted moreover that no refinements of coagulation technic were employed in the pre-treatment. The only control of alum application was the appearance of the treated water.

Contrasting with the pre-treated water, the untreated water when filtered seldom produced negative tests for *Esch. coli* in all five tubes even when filtered turbidity was at a minimum. All of the better samples were produced with alum treated filter-aids, the use of which is not recommended for the field due to numerous variables involved.

To sum up, the uncoagulated filtered water total counts at 37°C. were six times the coagulated filtered water counts, the 20°C. counts were fourteen times and the *Esch. coli* positives 25 times more numerous in the uncoagulated filtered water than in the water filtered after coagulation and settling.

It is noteworthy that clarity of pre-treated filtered water was uniformly excellent with the single exception previously mentioned, while the untreated filtered water frequently showed measurable turbidity. These observations have been confirmed in hundreds of cycles of operation during which the clarity of pre-treated filtered water was never in doubt. It should be stated that all turbidities of 0.1 ppm. or less have been recorded as 0.1 ppm. In a majority of such cases no measurable turbidity was detectable in the St. Louis turbidimeter which was employed.

Units Developed

Two sizes of equipment have been produced. One has 3.6 sq.ft. of filter area with nominal capacity 15 gpm., suitable for pack transport and weighing about 50 lb. The other has 10 sq.ft. of filter area with nominal capacity 50 gpm., suitable for motor trans-

TABLE III

Bacteriological Examination of Water Collected From Diatomite Filters Coagulated and Settled Unchlorinated

Run No.	Chem. lb/tank	Settling Hr.	Filter-Aid	Source	Total Count		*Esch. coli*					Turb. ppm.
					37°C.	20°C.	.001	.01	.1	1.0	10	
134				Raw								40
134	2 B.A.	1		Settled	13	180					5/5	10
134			535	Filtered	0	60					1/5	0.1
135				Raw	300	13,000	0/1	0/1	1/1	1/1	1/1	50
135	2 B.A.	1		Settled	50	100					5/5	20
135			535	Filtered	0	2					0/5	0.1
136				Raw	400	34,000	0/1	0/1	0/1	1/1	1/1	55
136	2 B.A.	1		Settled	40	200					5/5	20
136			535	Filtered	1	3					0/5	0.1
150				Raw	1,500	4,000	0/1	0/1	1/1	1/1	1/1	42
150	1 Fer.	2½		Settled	150	1,000					5/5	20
150			503	Filtered	20	100					0/5	0.1
151	1 Fer.	2½	503	Settled	200	400					5/5	20
151			503	Filtered	30	25					0/5	0.1
152				Raw	6,000	5,000	0/1	0/1	1/1	1/1	1/1	42
152	1 Fer.	1		Settled	300	450					5/5	20
152			503	Filtered	10	20					1/5	0.1
187				Raw	2,500	60,000	0/1	1/1	1/1	1/1	1/1	200
187	1 B.A.	1		Settled	1,000	20,000					5/5	44
187			545	Filtered	56	12,000					5/5	1.5
188	2 B.A.	2		Settled	400	4,000					2/5	25
188			545	Filtered	6	400					0/5	0.1
189	2 B.A.	1½	545	Filtered	5	480					0/5	0.1
212	2 B.A.	1	D-40	Filtered	6	20					0/5	0.1
213	2 B.A.	1	Sp. Plus	Filtered	4	8					0/5	0.1
215	2 B.A.	1	545	Filtered	6	11					0/5	0.1
225	2 B.A.	1	D-40	Filtered	2	170					0/5	0.2
227	2 B.A.	1	545	Filtered	2	20					0/5	0.2
226	2 B.A.	1	Sp. Plus	Filtered	1	78					0/5	0.1
261	2.2	2	535	Filtered	4	51					0/5	0.1
262	1.5	1	535	Filtered	5	30					0/5	0.1
263	1.8	1	535	Filtered	95	320					0/5	0.1
264	2	1½	535	Filtered	84	140					0/5	0.1
265	1.6	1	535	Filtered	17	90					0/5	0.1
266	1.7	3	535	Filtered	6	12					0/5	0.1
267	2.1	1	535	Filtered	7	10					0/5	0.1
268	3.3	1	545	Filtered	8	3,000					0/5	0.1
269	2.3	2½	545	Filtered	2	1,500					0/5	0.1
271	3.5	1	535	Filtered	50	91					0/5	0.1
272	3.6	2	535	Filtered	20	30					1/5	0.1
273	1.2	2	535	Filtered	240	120					2/5	0.1
274	1.6	3	535	Filtered	2	40					0/5	0.1
275	1.8	1	545	Filtered	20	85					0/5	0.1
276	2.1	2½	545	Filtered	5	10					0/5	0.1
277	2.4	1	545	Filtered	8	17					0/5	0 1
278	2.5	2	535	Filtered	6	8					0/5	0.1

B.A.—Black Alum Fer.—Ferrisul

rinous taste but with uniform residual chlorine of 1 ppm. plus or minus 25 per cent. It is believed that the introduction of the chlorine in advance of filtration adds materially to the safety of the procedure.

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135			535	Filtered	0	2					0/5	0.1
136				Raw	400	34,000	0/1	0/1	0/1	1/1	1/1	55
136	2 B.A.	1		Settled	40	200					5/5	20
136			535	Filtered	1	3					0/5	0.1
150				Raw	1,500	4,000	0/1	0/1	1/1	1/1	1/1	42
150	1 Fer.	2½		Settled	150	1,000					5/5	20
150			503	Filtered	20	100					0/5	0.1
151	1 Fer.	2½	503	Settled	200	400					5/5	20
151			503	Filtered	30	25					0/5	0.1
152				Raw	6,000	5,000	0/1	0/1	1/1	1/1	1/1	42
152	1 Fer.	1		Settled	300	450					5/5	20
152			503	Filtered	10	20					1/5	0.1
187				Raw	2,500	60,000	0/1	1/1	1/1	1/1	1/1	200
187	1 B.A.	1		Settled	1,000	20,000					5/5	44
187			545	Filtered	56	12,000					5/5	1.5
188	2 B.A.	2		Settled	400	4,000					2/5	25
188			545	Filtered	6	400					0/5	0.1
189	2 B.A.	1½	545	Filtered	5	480					0/5	0.1
212	2 B.A.	1	D-40	Filtered	6	20					0/5	0.1
213	2 B.A.	1	Sp. Plus	Filtered	4	8					0/5	0.1
215	2 B.A.	1	545	Filtered	6	11					0/5	0.1
225	2 B.A.	1	D-40	Filtered	2	170					0/5	0.2
227	2 B.A.	1	545	Filtered	2	20					0/5	0.2
226	2 B.A.	1	Sp. Plus	Filtered	1	78					0/5	0.1
261	2.2	2	535	Filtered	4	51					0/5	0.1
262	1.5	1	535	Filtered	5	30					0/5	0.1
263	1.8	1	535	Filtered	95	320					0/5	0.1
264	2	1½	535	Filtered	84	140					0/5	0.1
265	1.6	1	535	Filtered	17	90					0/5	0.1
266	1.7	3	535	Filtered	6	12					0/5	0.1
267	2.1	1	535	Filtered	7	10					0/5	0.1
268	3.3	1	545	Filtered	8	3,000					0/5	0.1
269	2.3	2½	545	Filtered	2	1,500					0/5	0.1
271	3.5	1	535	Filtered	50	91					0/5	0.1
272	3.6	2	535	Filtered	20	30					1/5	0.1
273	1.2	2	535	Filtered	240	120					2/5	0.1
274	1.6	3	535	Filtered	2	40					0/5	0.1
275	1.8	1	545	Filtered	20	85					0/5	0.1
276	2.1	2½	545	Filtered	5	10					0/5	0.1
277	2.4	1	545	Filtered	8	17					0/5	0.1
278	2.5	2	535	Filtered	6	8					0/5	0.1

B.A.—Black Alum Fer.—Ferrisul

TABLE IV

Bacteriological Examination of Water Collected From Diatomite Filters Unsettled

Run No.	Filter-Aid	Source	Total Count		*Esch. coli*					Turb. ppm.
			37°C.	20°C.	.001	.01	.1	1.0	10	
114		Raw		16,000	0/1	0/1	0/1	1/1	1/1	90
114	Sorbocel	Filtered (5 min.)		16,000					5/5	2.0
114	Sorbocel	Filtered (40 min.)		3,600					5/5	0.9
118		Raw		12,000	0/1	0/1	0/1	1/1	1/1	85
118	228V	Filtered (5 min.)		140					2/5	0.2
118	228V	Filtered		150					0/5	0.1
122		Raw		700	0/1	0/1	1/1	1/1	1/1	75
122	228V P. 535 B.F.	Filtered (5 min.)		80					5/5	0.5
122	228V P. 535 B.F.	Filtered (60 min.)		100					5/5	0.5
158		Raw	600	60,000	1/1	1/1	1/1	1/1	1/1	60
158	Sorbocel	Filtered	180	20,000					5/5	0.1
160	235V	Filtered	700	480					4/5	0.1
163		Raw	550	1,000	0/1	0/1	0/1	1/1	1/1	60
163	235V	Filtered	6	125					2/5	0.1
164	236V	Filtered	5	3,000					2/5	0.1
165	236V	Filtered	6	1,500					1/5	0.1
166	236V	Filtered	30	2,100					2/5	0.1
167		Raw	200	3,000	0/1	0/1	1/1	1/1	1/1	45
167	Sorbocel IV	Filtered	20	325					4/5	0.1
168	Sorbocel IV	Filtered	33	450					5/5	0.1
169	Sorbocel IV	Filtered (30 min.)	23	450					5/5	0.1
169	Sorbocel IV	Filtered (130 min.)	12	220					4/5	0.1
174		Raw	100	10,000	0/1	0/1	0/1	0/1	1/1	20
174	233V	Filtered	10	400					1/5	0.1
175	Mollicel	Filtered	50	3,000					4/5	0.1
176	Mollicel	Filtered	35	2,500					4/5	0.1
178		Raw	225	25,000	0/1	0/1	0/1	0/1	1/1	20
178	545	Filtered	40	10,000					5/5	3.0
179		Raw	150	6,500	0/1	1/1	1/1	1/1	1/1	18
179	545	Filtered	40	2,600					4/5	0.5
180	545	Filtered	60	3,500					5/5	0.5
181	545	Filtered	50	6,500					5/5	0.1
184		Raw	100	16,000	0/1	0/1	1/1	1/1	1/1	30
184	545	Filtered	50	12,000					5/5	3.0
185	545	Filtered	6	3,000					5/5	0.1
186		Raw	200	28,000	0/1	0/1	1/1	1/1	1/1	30
186	545	Filtered	180	4,000					5/5	0.1
290	Hyflo	Filtered	500	4,000					5/5	4.0
291	Hyflo	Filtered	450	5,000					5/5	3.0
292	Hyflo	Filtered	250	5,500					5/5	3.0
293	Hyflo	Filtered	360	5,000					4/5	1.2
294	Hyflo	Filtered	200	4,500					5/5	4.0

P.—Pre-coat B.F.—Body Feed

TABLE V

Bacteriological Examination of Water Collected From Diatomite Filters Unsettled

Run No.	Chem. lb/tank	Settling Hr.	Filter-Aid	Source	Total Count		*Esch. coli*					Turb. ppm.
					37°C.	20°C.	.001	.01	.1	1.0	10	
153				Raw	2,000	10,000	0/1	0/1	0/1	1/1	1/1	45
153	0.1 Fer.	0		Settled	350	3,600					5/5	
153			Hyflo	Filtered	40	85					1/5	0.2
154				Raw	1,000	2,000	0/1	0/1	0/1	1/1	1/1	45
154	0.1 Fer.	0		Settled	400	4,800					5/5	
154			Hyflo	Filtered	45	250					4/5	0.2
155	0.1 Fer.	0		Settled	350	7,600					5/5	45
155			Hyflo	Filtered	100	450					4/5	0.3

Fer.—Ferrisul

port and weighing about 350 lb. In both cases the filter unit includes the slurry feeder, necessary valves and fittings for attachment of hose and pump. The pump in each case is a separate item and operation of the filter unit depends only upon the delivery of water from the pump and access to the pump suction. Thus any centrifugal pump may be used within the pressure limits of the equipment. The power requirements of the slurry feeder are supplied by the water passing through the filter and these are insignificant.

The pump and engine for the pack filter weighs about 60 lb. and is mounted on a packboard. An assembly of the pack filter with pump and necessary hose is shown in Figure 5. This unit is suitable not only for fast moving troops where a capacity of 5 gpm. might suffice but also to replace the present portable sand filter and treatment section weighing together 800 lb. and rated at 10 gpm.

The pump and engine set for the 50-gpm. unit is the current item supplied with portable sand filters and weighs

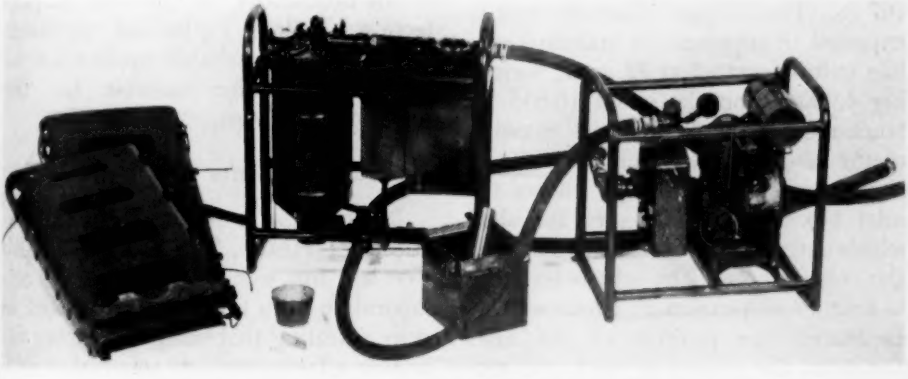

FIG. 5. Pack Filter With Pump and Hose

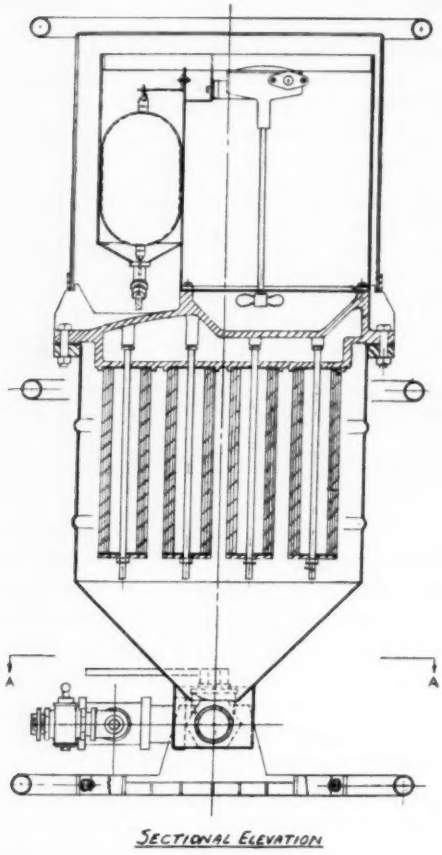

FIG. 6. Cross-Section of 50-gpm. Filter Unit

167 lb. The 50-gpm. diatomite unit is expected to supplant the standard mobile unit, overrated at 75 gpm., weighing 4,900 lb. on skids and 16,645 lb. truck-mounted. A sectional drawing of the 50-gpm. filter unit assembly is shown in Figure 6. This shows the inlet box at the bottom of the shell where entrance velocities are dissipated, the conical bottom by which filter-aid is kept in suspension and backwash is facilitated, the position of the filter elements, the collecting head, the suction float box controlling entrance of slurry to the pump suction, and the slurry tank with water motor agitator driven by pressure from the filter shell and supplying water for dilution and displacement of the slurry. The flow is upward during filtration and downward during backwash.

Each of these filter units requires a set of canvas tanks, hose and pumps for storage, pre-treatment and delivery to tank trucks or other conveyances. For the larger unit the 3,000-gal. canvas tank is suitable. The smaller unit can also be used with 3,000-gal. tanks but 500-gal. tanks are better suited for ease in handling and for treatment procedure, rapid filling of a tank promoting rapid coagulation and settling.

Conclusion

Development of diatomite filtration equipment for troops has proceeded under unique conditions. The underlying principles, characteristics and behavior had to be determined simultaneously with development of component parts, methods and technics with an eye to their application in a form suitable for the field and concurrently with tests under typical raw water conditions constantly changing. The development in the present form is not necessarily the ultimate of perfection. It does, we believe, represent a sound and workable application of diatomite filtration suitable for the needs of the troops.

Acknowledgments

Much credit is due the National Institute of Health, U.S. Public Health Service, for work performed in collaboration with the Engineer Board in demonstrating that diatomite water filtration effects complete removal of such chlorine resistant organisms as the

cysts of *Endameba histolytica* and Cercarie causing Schistosomiasis. These results (unpublished) were early reported to the Office of the Surgeon General and to the Committee on Sanitary Engineering, National Research Council, which organizations have given valuable counsel. The demonstrated efficiency of diatomite filtration focused attention on this process and stimulated further development.

It is desired to express appreciation for the cooperation of various manufacturers who built pilot models to meet specifications while they were in evolution. The list includes the Permutit Co.; Wallace and Tiernan Co., Inc.; Infilco, Inc.; S. F. Bowser Co.; Titeflex, Inc.; and Proportioneers, Inc.

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Symposium on Water Works Management and Administration

By Wendell R. LaDue

THE consideration of the problems of water works management in time of peace might well be termed an academic endeavor. In time of war, however, the management of a water utility involves an essential industry directly engaged in the production of one of the most vital of the materiel of war. The successful production of water is carefully geared to the adequate functioning of all activities of the "home front," hence its importance.

The need for a study of top management in water utilities and the determination of good practice in organization were very forcibly brought to the attention of the Association by Past-President Howson in a paper presented at the Indiana Section meeting in April 1941 and published in the July 1941 JOURNAL. As a direct result of Past-President Howson's plea, the Board of Directors at Toronto, in June 1941, authorized the formation of the Committee on Municipal Water Works Organization, consisting of 25 men, carefully selected to represent all sections of the country, for research into existing conditions and basic laws.

To facilitate handling of returns, the country was further divided into three regions:

1. Pacific—comprising 15 states.
2. Central—comprising 17 states.
3. Atlantic—comprising 16 states, the District of Columbia and Canada.

Speaking for these areas at the Milwaukee Conference were John S. Longwell (see page 1224), D. L. Erickson (see page 1230), and Charles E. Moore (see page 1236).

Problems and Forms of Water Works Management

The water works profession generally deems it essential that top management of the utility shall have:

1. Freedom to formulate policy.
2. Freedom to establish rate structure.
3. Freedom to control funds for expansion.
4. Freedom to control personnel.
5. Freedom to purchase materials and enter into contracts.
6. Freedom in long-term planning and development.

To attain these freedoms and services there has been a tendency to establish boards, commissions and au-

Introduction to Symposium on Water Works Management and Administration held at the Milwaukee Conference on June 14, 1944, by Wendell R. LaDue, Supt. and Chief Engr., Bureau of Water and Sewerage, Akron, Ohio, and Chairman of Committee on Water Works Organization.

thorities to manage public utilities, said organizations being sometimes but loosely controlled by the general municipal organization.

Successful operation of a water works, sewerage system, or other type of municipally owned and operated utility, requires that top management have the confidence of the community if it is to merit these freedoms. Unfortunately existing basic laws do not always provide for such fundamentals. Again, we must admit that a uniform system of top management is not always possible or perhaps even desirable. Past history and local conditions always claim consideration, for it should be remembered that it is often hard to convince a given citizenry, fixed and satisfied with a *bad old* method, that it should forget the old and adopt a *new,* (to them) untried method, regardless of how *good* it may have been proven *elsewhere.* Again it can be said in general, the public gets what it wants, good or bad. And let us remember that the manager is a public servant, which means he serves the public with its needs and requirements, as they may be presented to him or demanded of him.

All too often management is considered to be the more or less routine operation behind the delivery of a supply of potable water to the consumer's tap. It is far more than that. It embraces sound planning for the future and the coordination of those future needs with the financial ability of the utility to provide them. Management provides a smooth routine of continuing operation so that when future needs become urgent, adequate planning (both physical and financial) has already foreseen and has made possible the carrying out of those needs with the least possible disturbance to the utility and its customers.

Water Works Management and Administration in California

By J. S. Longwell

IN cooperation with the State Council of Defense, the California Railroad Commission in 1942 prepared a report listing all privately- and publicly-owned water utilities operating in California and giving the number of consumers served by each utility. Excluding those utilities which provide water for irrigation only, the report showed the number delivering water for domestic use to be as follows:

	Number	*Consumers*
Privately Owned.....	746	416,956
Publicly Owned.....	180	1,087,350
Total.....	926	1,504,306

All of the 746 privately-owned water utilities operate under the jurisdiction of the Railroad Commission, whereas those publicly owned are regulated entirely by the governing body under which they function.

Privately-Owned Utilities

In supervising privately-owned water utilities, the Commission regulates rates to insure an adequate return on the investment; establishes standard accounting practices; develops uniform regulations governing water service to consumers and the extension of water mains and facilities; has supervision over new financing; assists or advises in connection with the adjustment of consumer complaints; and performs such other regulatory functions as are required.

The Railroad Commission, with its many years of experience in the supervision of these utilities, has developed practical and efficient methods of control, and its jurisdiction has proven eminently satisfactory.

Publicly-Owned Utilities

Many publicly-owned utilities in California were formerly privately owned, having been acquired through purchase by the municipality or group of municipalities under which they now operate, while others were developed by the municipalities and have grown and expanded with the communities which they serve. Utilities purchased by the present owners after they had been under the control of the Railroad Commission have in many cases continued operations under public ownership in much the same manner as followed under private ownership, but with certain modifications to conform to municipal practices. Utilities purchased prior to the creation of a Railroad Commission and those which have

A paper prepared for but not delivered at the Milwaukee Conference because of transportation difficulties, by J. S. Longwell, Chief Engr. and Gen. Mgr., East Bay Municipal Utility District, Oakland, Calif.

always been publicly owned have worked out their plan of management and control in accordance with the special requirements of their particular municipality. Some have advanced with the growth in population and have revised their procedures accordingly; others still retain practices which have been outmoded for some time and need substantial and appropriate rehabilitation.

Individual Municipalities

For the purpose of obtaining a good cross-section of the utilities as operated throughout the state, eleven municipalities, varying in population from 11,300 to 1,504,000 and with a total population of 3,187,000, were selected for study. This represents about 43 per cent of the state's population at the time of the survey.

Ten of these municipalities function under a freeholders' charter and one under the State Municipal Code without charter. Freeholders' charters definitely outline all branches of the city government and publicly-owned utilities; they are adopted by a vote of the city electorate and are confirmed by act of state legislature. Any city with a population of 3,500 or more may adopt such a charter and be guided thereby.

Out of the ten municipalities with freeholders' charters, four had commissions, boards of public works, or similar bodies for the direct control and operation of the water utilities. In all four cases the board or commission was appointed by the mayor and confirmed by the city council. In three cases the water utility reported directly to the mayor and city council; two cities had water departments or utilities which reported to the city manager; and in one case the water utility and its superintendent reported to the city engineer who in turn reported to the city manager. In the case of the city operating without charter under the Municipal Code, the water utility and its superintendent reported directly to the mayor and city council.

Only five of the eleven municipalities, or less than half, had adopted civil service systems for the water utility employees, and in only one case was the manager of the water utility under civil service.

During the past few years, considerable thought and attention has been given by the American Water Works Association to the matter of improving the organization plan for publicly-owned utilities. One of the items given special consideration was the development of a model form of water utility organization for municipalities, which would remove the utility from other branches of the city government and prevent, as far as possible, any political interference, and which could be recommended by the Association for incorporation in legislation, making its use mandatory by municipalities within the state. This matter was presented to the eleven municipalities canvassed in California, with the following results:

In favor of mandatory model form of organization	2
Not in favor of mandatory model form of organization	5
No expression of opinion	4

Seven cities stated that they were not in favor of any increase in state supervision, and four expressed no opinion on this feature.

It is apparent from the results of this canvass that no increase in state supervision such as is applied to privately-owned utilities is desired, and that the majority of the various California cities

wish to work out their own plans for water utility management rather than to follow any legislative action or a model plan. In all municipalities functioning under a freeholders' charter, any changes or improvements desired in the operation of the water utility can be effected by a charter amendment voted by the electorate and later confirmed by the state legislature. It may therefore be stated that it is directly the responsibility of the individual cities to make such amendments as are necessary to improve their water utilities. Five of the cities expressed themselves as satisfied with the present form of water utility organization; two were not satisfied; and four failed to express any opinion on this item. It is probable that those who failed to give an answer are not fully satisfied with the present plan of operation.

From the investigations made, it is safe to say that the most satisfactory form of organization for the individual municipality is that in which a water commission or board is set up, separate from the city government, and having complete charge of the operation of the utility. This type of organization, operating under civil service, largely removes the utility from politics and places the regulation and disposal of funds in the hands of the commission or board, as it should be. In some California cities operating under this plan, charter changes are needed to give the water commission more complete control of funds. In such a set-up, the commission or board usually consists of five commissioners or directors appointed by the mayor and confirmed by the city council, with their terms staggered to insure continuity of policy. The commission or board appoints its manager or superintendent, who is responsible to the commission or board for the operation of the utility. Members of such commissions, for the most part, have been outstanding citizens who serve with little or no compensation as a civic duty. This form of utility management is in effect in Los Angeles, San Francisco, Long Beach, Palo Alto, and a number of other cities.

Notwithstanding the inherent weakness of the plan, very good results have fortunately been obtained in some of the cities where the water utility and its manager report directly to the city manager or to the city council. This arrangement is undoubtedly subject to more political interference than in the case of those with independent commissions or boards, and the water utility funds are naturally subject to more ready diversion to the general city fund instead of being held for proper upkeep and expansion of the utility. It is the opinion of many who have studied the situation over a long period of years that this form of organization and management should eventually be supplanted, with the control placed under a separate commission or board.

Judging from the results of the survey and from a general knowledge of conditions throughout the state, it is very doubtful if any legislation could be enacted making mandatory the adoption of a model form of water utility organization. It is believed, however, that through the A.W.W.A. and by cooperation among the water works men, progress can be made toward standardizing organizations along improved lines. Such model organizations can be outlined and publicized and information can be made available to the various cities. This should no doubt be done in the individual cities to fit local requirements best. The adoption of such plans in Cali-

fornia would, of course, require action by individual cities through charter amendments.

The foregoing discussion has been confined to forms of water utilities operated by individual municipalities. Legislation has also been enacted in California which permits the formation of various types of districts wherein cities, public agencies and unincorporated territories may combine for the development and distribution of water supplies.

Municipal Utility Districts

The Municipal Utility District Act provides that two or more cities or other public agencies, together with unincorporated territory in the same or different counties, may organize and incorporate as a utility district.

Such districts, among other things, have the right of eminent domain and may acquire, own, construct, operate, control or use within or without, or partly within or without the district, works for providing light, water, power, heat, transportation, telephone service, or other means of communication, or means for collection, treatment, or disposition of garbage, sewage or refuse matter.

The Act provides that districts so organized shall be governed by a board of directors composed of five citizens elected at large with one from each of five wards. They shall serve four years and shall receive compensation in the amount of $10 per meeting, but with pay for not more than two meetings per month. The board appoints the district officers, and the balance of the employees, with a few specified exceptions, are appointed by the general manager from civil service eligible lists. The general manager is the head of the civil service system, as definitely outlined in the Act. A retirement system may be established at the option of the board.

Several such districts have been formed, but the only one in actual operation is the East Bay Municipal Utility District, comprising the cities of Oakland, Berkeley and seven other cities, together with large areas of adjacent unincorporated territory, all on the easterly side of San Francisco Bay. The District covers an area of 187 sq. mi. and serves a population now estimated at over 800,000.

The District was formed to develop a new source of water supply for the area and to acquire the facilities of a private water company then supplying the territory but not in position to take care of possible future expansion. This has been carried out and water is now developed, distributed and delivered by the District to all consumers in all of the cities and throughout the unincorporated territory.

Rules and regulations governing water service to consumers and the extension of water mains are established by the Board. It also establishes water rates, has full jurisdiction over all of the business of the District, and is entirely independent of any city or other public agency within the District.

Under this plan of organization, it has been possible to obtain Board members of high caliber and to operate strictly on a practical and efficient business basis. Thus far the activities of the District have been confined to water supply, together with the generation of hydro-electric power at the principal storage reservoir, which power is sold wholesale at the plant to a privately-owned power company. The powers of the District are, however, quite broad and such a district may engage in many other types of ac-

tivity if it appears to be to the best interests of the community.

Municipal Water Districts

Under the State Municipal Water District Act, one or more municipal corporations in any county, with or without unincorporated territory in such county, may organize a municipal water district. Municipal corporations and the unincorporated territory need not be contiguous but must all be within one county.

Control of such districts is centered in a board of five directors, one director to be elected by vote of the electors in each of five divisions of the district. Board members serve for four years, with terms staggered to provide continuity of policy, and receive a salary of $10 per meeting but for not more than three meetings per month. The board appoints a general manager to serve as the executive officer in charge of the administration of the district's activities, and also appoints such other officers as are required.

A municipal water district may acquire or construct water works and facilities for developing, transmitting and distributing a domestic water supply to the consumers of the district. It may also operate, maintain and extend such facilities and do all things necessary to provide an adequate water supply. Taxes may be levied as required. Funds may not be diverted to any member city or public agency, as the district, in its operations, is a definite entity. It may own and operate all water facilities within any of the member cities or public agencies.

A number of such districts exists in the state. Probably the largest is the Marin Municipal Water District, which provides water to San Rafael, Sausalito, Mill Valley, as well as to other neighboring cities and to unincorporated territory. This is a very successful and well-managed district now serving some 15,000 consumers. The employees of the District are not under a civil service plan, but a pension system has been in effect for many years.

This form of district is restricted to water utilities and does not provide the broad functions of a utility district. It is, however, well suited for the use of a number of cities and agencies or unincorporated territory within one county desiring to provide a water supply for such an area, and the Act is well drawn to permit efficient and satisfactory operation.

Metropolitan Water Districts

This form of district differs from the two previously described in that the Act is designed to permit a group of cities to organize for the purpose of developing a new source of water supply, the water to be sold at wholesale to the member cities. The Act was drawn to meet the particular needs of thirteen cities and one municipal water district in the southern part of the state which were desirous of obtaining an additional supply. This agency is designated the Metropolitan Water District of Southern California.

District control is under the direction of a board of directors appointed by the mayor and confirmed by the councils of the member cities, with at least one director from each municipality. Municipalities may elect to appoint additional directors, but the number shall not exceed one to each $200,000,000 of assessed valuation. The directors of each municipality shall cast their votes as a unit.

The board is empowered to levy taxes as required to take care of expenses over and above the operating income. Such taxes may be paid by

the member municipalities in lieu of assessment against property owners.

The Metropolitan Water District of Southern California has recently completed its herculean task of bringing water from the Colorado River to the coastal plain of southern California at a cost of over $200,000,000. This form of district has been highly satisfactory. Board members have been largely business and professional men of broad experience and outstanding ability, and the District has been exceptionally well managed. Water is now available and is being distributed to the member municipalities as required.

Summary

In general, ample legislation has been provided in California to permit any city, group of cities and unincorporated territories to work out a satisfactory form of water utility management and administration. There seems to be a definite objection on the part of the publicly-owned utilities to any broadening of state supervision and a feeling that each community should determine its own requirements rather than to have legislation making mandatory any specific form of water utility.

The water utility is a definite revenue-providing business, and it is the general opinion that its management should, as far as practical, be independent of the other departments of municipal government. The Association, through its Committee on Municipal Water Works Organization, has made a good start on its investigation and study of this subject, and the work should be continued as war conditions permit, in an effort to encourage changes in legislation where required and the adoption of improved forms of organization.

Regardless of the type of water utility management, if satisfactory operating results are to be obtained it should be the aim of all engaged in this important and essential industry to work toward the creation of organizations which will cause the personnel to feel that water utilities are good organizations to be with, and that such work is a life career and not a temporary political appointment. To bring this about, it is necessary that an adequate civil service system be in effect to insure tenure of office for the entire personnel. There should be a satisfactory pension plan to provide for old-age and disability retirement of those who have devoted their work years to the utility.

Careful consideration should be given to the matter of employee relations and the establishment of a rational method of handling this problem. In line with practice in industry, some California water utilities have worked out a classification and job analysis program. This has involved the preparation of descriptions and specifications for all jobs or positions, and finally the evaluation of those positions. With such a program, it is possible to classify properly all positions and to adjust the wage scales or salaries so that they are in line with the duties performed and also in line with salaries paid in other industries. If this procedure is accompanied with the establishment of proper salary ranges and a definite procedure is adopted relative to salary advancement, employee relations will in most cases be greatly improved. With the growing unionization of water utility employees, this matter is becoming increasingly important and should receive the careful consideration of all water utilities, both privately and publicly owned. By doing so, it may be possible to anticipate and avoid many operating difficulties.

Water Works Management and Administration in Nebraska

By D. L. Erickson

IN order to be able to visualize the management of water works in Nebraska, it is desirable to have a general understanding of the statutes relating to municipal government in the State.

The Nebraska Statutes divide the municipalities in the State into the following five general classes:

1. Metropolitan cities, being cities having a population of 100,000 or more. Omaha is the only city in the State in this class.
2. Cities of the first class having a population of more than 40,000 and less than 100,000. Lincoln is the only city in the State in this class.
3. Cities of the first class having a population of more than 5,000 and less than 25,000. There are fourteen cities in the State in this class.
4. Cities of the second class having a population of more than 1,000 and less than 5,000. There are 93 municipalities in this class.
5. Villages, being communities having a population of more than 100 and less than 1,000. There are 420 communities in this class.

The Statutes treat each of the foregoing classes of cities separately, as a result of which a large number of variations occur in laws and procedures.

In addition to the statutes relating to the foregoing different classes of cities, there are three additional general laws which are superimposed on municipal government:

1. The first of these is a Nebraska constitutional provision which permits any city having a population of over 5,000 to adopt a home rule charter by a majority vote. Three cities in the State have taken advantage of this charter provision and as a result are themselves able to legislate on matters of local concern without having to go to the state legislature.
2. The second is a statute permitting any city having a population of more than 2,000 to adopt a commission form of government by a majority vote. There are three cities in the state operating under a commission form of government.
3. The third is a statute provision permitting cities having a population of more than 1,000 but not more than 100,000 to adopt a city manager plan of government. One city

A paper presented on June 14, 1944, at the Milwaukee Conference by D. L. Erickson, City Engr. and Director of Dept. of Parks, Public Property and Improvements, Lincoln, Neb.

in the state is operating under the city manager plan.

Neither the commission form nor the manager plan interferes with or prevents a city from adopting a home rule charter.

Lincoln, Nebraska, is unique in that after having adopted the commission form of government in 1913, it adopted a home rule charter in 1919, and then in 1935 it amended this charter in such a manner as to abandon the commission form and adopt a new plan of government headed by a mayor with a two-year term and six councilmen with four-year terms, all elected on a non-partisan ballot. All executive, legislative and judicial powers and duties are lodged in the council. Under the direction of the council the affairs of the city are administered by three directors appointed by the council. The present form of city government in Lincoln has been termed by some as a modified manager form with three directors or managers reporting directly to the city council.

There are three additional Nebraska statutory provisions, relating to water works management:

1. The first of these authorizes the creation of a metropolitan utilities district in metropolitan areas. Omaha adopted this plan of operating its water works system in 1913, and at the present time, the District is furnishing water, gas and a small amount of ice to the citizens of Omaha.

The Metropolitan Utilities District of Omaha is a separate political subdivision and is independent of the city government. It is managed by a bi-partisan board of six directors, each serving a six-year term with two directors—one from each major political party—being elected every two years. The directors receive a salary of $50.00 per month.

2. The other provisions permit cities of the first and second classes to operate their water works through a board of public works, which is appointed by the mayor and council. Nine cities in the state are now operating their water works systems under this plan.

(a) A law passed in 1901 by the Nebraska Legislature permits the mayor and council in cities of the first class (5,000–25,000) to appoint a board of public works consisting of three members, residents of the city, the salaries of each board member to be a fixed maximum of $100.00 per annum; except that if this board has active direction and supervision of the water works system, the salary may be $5.00 per member per regular meeting with a maximum of $260.00 per annum. The board is authorized to make contracts on behalf of the city for the performance of work and erection of improvements as may be ordered by the mayor and council. This statute is quite indefinite in many respects, and as a result many legal questions have arisen in connection with the operation of water works under this plan in cities of this class.

(b) In 1935, the Legislature passed a similar law applying to cities of the second class and villages which is much more satisfactory. This act authorizes the city council by ordinance to create a board of public works consisting of not less than three or more than six members, residents of the city, who are appointed by the mayor and council. The members of this board have a three-year term. The maximum

salary of the board members is $150.00 per annum. The board has the power to operate any utility referred to it and to exercise all powers conferred by law upon such cities for the operation and government of such utility to the same effect, in the same manner, and under the same restrictions, as the city council could do if no board of public works existed; except, however, that the board shall not make any expenditures or create any indebtedness other than for ordinary running expenses in excess of $1,000.00 without first obtaining the approval of the city council. The board, however, is required to report to the city council at such regular intervals as the council may require.

Generally speaking the statutes pertaining to the various classes of cities are fairly uniform with respect to the provisions relating to the city first going into the water works business. The governing body is given wide authority either to construct or acquire by purchase or condemnation the necessary plant, provided a favorable vote of the voters is secured, and to finance the cost by issuing general obligation bonds. In addition, cities of the first class only (5,000–25,000) may finance original construction, purchase or acquisition of water works, after a majority vote, by issuing revenue bonds.

Water Main Extensions

All cities in the state have legal authority to construct water main extensions without the vote of the electors. A statute applying to utility districts and to all municipalities except home rule cities authorizes the creation of special assessment water districts by ordinance of the city council or resolution of another governing body, describing the improvement and the property to be assessed. The law requires publication of the ordinance or resolution creating the district and further provides that if the owners of a majority of the foot frontage of the taxable property in the district file a protest within 30 days of the publication, the ordinance or resolution is repealed or rescinded. If no sufficient protest is filed the city or utility district may proceed with the construction.

On completion of the construction of the water extension, the actual cost of construction, not exceeding the cost of a 6-in. main, may be assessed against the property in the district on the basis of proportionate cost. The excess cost shall be paid out of the water fund or utility fund. There is an additional provision, however, that the entire cost may be assessed against the property in the district upon filing of a petition signed by the owners of a majority of the foot frontage in the district, containing the consent of the owners to the installation of the size mains designated in the petition and approved by the council or directors.

Some cities are still operating under an older law still in effect, applying to cities and villages, which limits the amount of the assessment to the sum of 50¢ per front ft. This old law also does not have the provision described above for assessing the entire cost against the property with the consent of the majority of the property owners.

A recent statutory amendment also gives the Omaha Metropolitan Utilities District authority to issue revenue bonds without vote of the people, in an amount not exceeding a total of $500,000 outstanding at any one time.

Water main extension in Lincoln is governed by its Home Rule Charter,

which permits the city to create and construct water districts without petition, and assess the cost against the property in the district, without limitation as to the size of the mains, but not exceeding the special benefits accruing.

Water Liens

Nebraska cities of the first class (5,000–25,000) have statutory authority to assess water rentals delinquent three months as a special assessment against the property which becomes a lien. The Statute provides, however, that in the case of tenant customers the owners of the property must be given written notice whenever their tenants are 60 days delinquent in the payment of their water rent, and if the owner gives written notice to discontinue the water service then any water furnished to the occupants subsequent to said notice shall not be a lien against the property.

Cities of the second class and villages have similar authority to make water charges and rents a lien against the property but are not compelled to give written notice to the owner as required in cities of the first class.

The Omaha Metropolitan Utilities District has no specific legal authority to make delinquent water rents a lien against the property. In lieu thereof, the District requires a deposit to be paid when the original water connection is made and the application for service provides for forfeiture of this deposit in case the customer moves, leaving a delinquent account.

The Lincoln charter contains a specific provision giving the Council power to "provide that any tax for the use of water furnished by said City shall be a lien upon the property when the same is furnished."

Regulation of Rates

There is general agreement in the Nebraska Statutes applying to all municipalities and utility districts that the power to regulate water rates rests in the governing body of the municipality or utility district furnishing water service, and is not specifically subject to the control of any state regulatory body.

Nebraska has a State Railway Commission, but its jurisdiction is largely confined to rates and service in transportation, communications and other common carriers. However, in a recent case the court ruled that this commission did have jurisdiction over electric rates for service furnished in territory outside of city limits when a city was furnishing electrical service to customers situated beyond its corporate limits. This question has so far not been raised in the case of water rates.

State Budget Law

The 1943 State Legislature enacted a State Budget Law applying to all activities of all municipalities except Lincoln and Omaha. These exceptions are now giving those municipalities affected considerable concern. This law requires all municipalities, with the exceptions mentioned, to prepare a detailed estimate of receipts and expenditures on a form prescribed by the State Auditor, hold a public hearing, and adopt a budget in advance of the fiscal year.

All departments and officials must limit expenditures to the budget after it is adopted, except that transfers within the same fund during the last two months of the fiscal year are permitted. In the case of catastrophes, accidents or emergencies or the extensions of municipal utilities arising after the adoption of the budget, additional

funds may also be provided therefor from unappropriated revenues, if any, in other funds, or from temporary loans.

Since the expenditures of a water department are more difficult to anticipate and estimate a whole year in advance than the costs of most other municipal functions, this new State Budget Law is quite unpopular among those water works officials affected. It is believed, however, that in general it is a good law which will not be too difficult to comply with after water works officials have had more experience in its operation. In its present form, this budget law may be found to be too rigid, in which case suitable amendments can be made in the future to make it more flexible.

Fire Protection Revenue

There is a lack of uniformity both with respect to the statutes relating to the authority of the cities to levy taxes to pay the water utility for fire protection service, and with respect to the practices of the cities having authority to levy such taxes. The Omaha Metropolitan Utilities District and all municipalities in the state except Lincoln may make an annual levy of 0.6 mill for fire protection purposes. The levy is optional, not mandatory, and is not universally included in annual estimates and appropriations. The Lincoln City Charter does not authorize the council to levy a general tax for fire protection service so that in Lincoln the water department does not receive any tax funds for this service.

Joint Operation of Water and Electric Utilities

It happens that a large proportion of the municipalities in Nebraska operate electric as well as water utilities, in which case the water and electric utilities are nearly always operated jointly. Considerable economies can be effected by joint use of plants, meter readers, and billing, clerical and administrative staffs. Furthermore, since the electric revenue is usually five times the water revenue, the combination of the two utilities in one organization creates sufficient annual revenue to justify the employment of adequate and competent administrative and engineering personnel which the water utility by itself might not be able to provide.

In Omaha, the Utilities District does not engage in the electric business, but it does manufacture and distribute artificial gas and a small amount of ice. In the operation of the water, gas and ice utilities, each division has its own production, distribution and engineering organizations; but all other functions are handled jointly, including billing and accounting, purchasing, legal and administrative operations.

The directors of the Omaha Metropolitan Utilities District are required to appoint a general manager who shall act as secretary of the Board of Directors and shall have general supervision of the management, construction, operation and maintenance of the utilities under the jurisdiction of the District subject to the direction of the board. The enabling statute specifically provides that "No one shall be appointed general manager who shall not possess business training, executive experience and knowledge of the development and operation of public utilities." The tenure and compensation of the general manager is determined by the Board of Directors.

Lincoln operates a combined water and electric department which furnishes electric energy for all water pumping and street lighting in the city and approximately 20 per cent of the resi-

dential and commercial business in the city. All functional organizations of this department are operated jointly, except distribution, which obviously requires separate crews for each utility.

Lincoln's water and electric utility is, by ordinance, designated as part of the Department of Parks, Public Property and Improvements. The director of this department is appointed by the city council and his compensation determined by the same body. At the present time this department includes: water and electric utilities, parks, streets, sewers, paving repair, plumbing and building inspection and the municipal airport. The director of this department is also city engineer.

In cities of the first-class (5,000–25,000) not having a municipal electric plant nor a board of public works, the statutes require a water commissioner to be elected. He has general control of the water works, subject to the direction of the mayor and council. There are at present seven elected water commissioners in the state. In cities of the same class having a water works and an electric plant, the water commissioner is appointed by the mayor and council and, subject to their direction, has general control of both utilities.

In cities of the second class (1,000–5,000) and villages the water commissioner is appointed by the mayor and council. Until 1937 he had to be a freeholder, but this limitation no longer obtains.

In both of the foregoing classes of cities and villages having a board of public works, this board takes the place of the water commissioner and appoints its chief executive who is either called superintendent or manager.

In cities operating under the commission form of government, the chief water works executive is the elected commissioner in whose department the water works is included.

In the single city in the state operating under the manager plan of government, the water works superintendent is appointed by the city manager. This city has also a municipal electric plant and the present city manager is a graduate electrical engineer.

Statistics

There are 412 municipal water works systems in Nebraska and one private water works system. In 1942 an American Water Works Association committee questionnaire was sent to the water works managers in the eleven leading cities in the state whose total population represented 76 per cent of the total urban population of the state. From the information thus secured, it was learned that the average investment per capita was $60.00, the average annual revenue per capita was $5.40 and the average ratio of investment to annual revenue was 11.11 : 1. If Omaha and Lincoln were excluded, the figures for the remaining cities would be $41.50, $5.05 and 8.22 : 1 respectively.

It is interesting to note that in response to the question, "Is the present form of management satisfactory, and if not, what changes should be made?" all except one of the water works managers of the cities in the list which were operating under either a utility district or a public works board were satisfied with the present form of management. Furthermore, a majority of those now operating under a city council expressed a definite desire for some kind of separate utility board so that the utilities could be administered separately and independently from the other municipal functions.

Municipal Utility Management in the State of Virginia

By Charles E. Moore

THE Virginia State Constitution provides for the organization and government of counties, towns and cities. The constitution requires an election by the people of certain specific officers, known as constitutional officers. It further provides for the creation of additional governmental units and officials by acts of the general assembly.

The constitution requires that in the formation of towns and cities the area to be so constituted be defined by metes and bounds, that towns must embrace a population of over 200 but less than 5,000, and that cities must have a population of more than 5,000.

General Assembly

Areas to be incorporated as towns and cities may petition the circuit court of the county where located. The petition must provide for the constitutional officers and minimum administrative officials. Further enlargement in the form of local government is generally obtained by an act of the general assembly.

First- and second-class cities, although geographically within, are entirely separate from the county surrounding it. Towns remain a part of the county in which they are located, even though having town officers and town taxes in addition to county officers and taxes.

The act of the general assembly giving to a locality a form of government is generally considered as "The Charter" for such local government.

Funds

Both the constitution and the code (acts of the assembly) specifically limit the indebtedness of all incorporated towns and cities. Generally this limitation is a function of the assessed value of the real property for the purpose of taxation.

There is, however, an exception to the statutory limitation. Where indebtedness is to be incurred for acquisition, construction or enlargement of a revenue-producing project, such indebtedness is not included in the general limitation, so long as such project is maintained on that basis of income necessary to meet all its financial obligations.

There are no specific constitutional or statutory provisions for the segregation of funds of the local government. Segregation may be and often is a matter of agreement between the locality and the trustees or banking institution sponsoring the local bond issues. Segregation of funds may be a part of the Charter's provisions.

A paper presented on June 14, 1944, at the Milwaukee Conference by Charles E. Moore, Mgr., City Water Dept., Roanoke, Va.

State Corporation Commission

The State Corporation Commission's concern with public utilities is primarily in the fixing of proper rates and charges for the service rendered. Up to this time, the State Corporation Commission has not assumed jurisdiction over the rates and charges of a municipally-owned utility. It would appear from a study of the constitution and the code, together with recent deliberations by the assembly in the matter of airport rates, that any attempt on the part of the State Corporation Commission to assume jurisdiction in the matter of rates and charges as to municipally-owned utilities would meet with objections upon the grounds of jurisdiction, with the result that the question would be resolved in favor of the municipality. However, there appears no bar to the taking of jurisdiction by the Commission on petition of the municipality.

It appears that any municipal corporation owning and operating a public utility in the state, may establish that form of organization and management that seems to it best, limited only to those common lay requirements providing for safe, sound and proper collection and expenditure of public funds, and the protection of public property, together with the rendering of an accounting therefor and fixing the entire responsibility for same.

A questionnaire was sent to all municipally-owned plants in this state which served a population of 5,000 or more. Data were accumulated from seventeen such cities.

The water department of one city was under the control of a board of water commissioners, twelve cities were under the council-city manager form of government, and the four remaining cities were under the mayor-common council type of government. Nine of the city water departments were under the direction of a manager and seven were under a plant superintendent, with one plant having both a manager and superintendent appointed by the governing body.

The commercial end of the water departments was handled by the regular constitutional officers in seven of the seventeen plants, and the other ten, including the one plant for which a manager and a superintendent were directly appointed by the governing body, had a commercial branch of its own.

The entire receipts for the sale of water immediately become a part of the general city funds in twelve of the cities, and are segregated for water department use exclusively in only five.

Postwar Planning

Believing the general trend in the operations of municipal utilities is toward sound economic practice together with the fact that present war restrictions are delaying needed expansion, it is believed timely that an ideal plan should be carefully compiled and made available for those communities faced with extensive expansion under troublesome financial conditions.

Pending the compilation of statutory provisions only a general outline is herein suggested for general guidance in the preparation of such a plan.

Organization

Private ownership of utilities has been the target of many, nevertheless the overall management efficiencies have generally been beyond criticism. Utmost success is only obtained by taking the best, without regard to its source.

It would appear sound therefore to design a pattern for a municipal organization for water supply systems

closely resembling that for private enterprise. After all, providing an adequate source of supply and making a satisfactory delivery to all customers at the lowest possible cost to the users and the community is just plain business.

A board of directors, commissioners, committeemen or whatever the title may be or may imply, should in fact be the governing unit, endowed with all the necessary powers to borrow money, buy, hold and sell real estate, contract and be contracted with, sue and be sued, employ a manager and delegate to him proper authority and to do any and all things pertinent to the successful construction, operation and management of a good water supply system, all in the name of a corporate title embracing the land, structures and equipment used and useful in such public service.

Management

The manager should be authorized and directed to take entire responsibility for the details of all operations, maintaining the system under a sound economic plan, provide for future expansion, institute a sound employment program, reporting to and receiving the approval of the directors at frequent and regular intervals.

Such a plan should be developed in detail and be accompanied by the necessary explanatory notes. It should be made available to all and would undoubtedly be advantageous to any community now at a disadvantage both physically and financially, but which with the end of the present war is very apt to find itself unable to cope with the future without undertaking a major change in its management features.

The facts and the conclusions heretofore set forth convincingly show that a reasonable percentage of municipally-owned water departments in Virginia now are operating under the basic outline of organization and management above suggested, and it remains for those others not now so organized to adopt such a plan should they in the future deem it necessary or advisable, without the creation of any new statutory provisions.

The question of making the state regulatory body the sole court of jurisdiction in the matter of municipal rates and practices in the preparation of a comprehensive plan would seem to be largely influenced by particular conditions with each municipality, irrespective of the state in which it is located.

Where the area and volume of business served and provided by a municipally-owned plant extends beyond its own corporate jurisdiction and is an appreciable percentage of its total responsibility, the statutory right of a reasonably representative group outside of the corporate area to appeal to an impartial body would doubtless serve a very useful purpose. On the other hand, as is true in the state of Virginia, where the area and volume served and provided by a municipally-owned water plant beyond its own corporate limits is relatively a small percentage of the whole, then and under these conditions the question of rates and practices is a family affair and a matter undoubtedly best left in the hands of the local government.

Any general outline, therefore, providing for the determination of the questions of rates and practices at the hands of the state regulatory body should recommend such procedure only where municipal plants predominantingly serve an area materially beyond its own jurisdiction.

Discussion of Papers on Water Works Management and Administration

By Gerald E. Arnold

IT has been my privilege, the last two and one-half years, to visit many water systems throughout the country, particularly in the eleven western states. During these visits, while on official business, I have noted a number of factors which I believe will be of interest to water works men in plant management and operation.

The business offices of water works in many instances are not a credit to the utility. Offices are frequently located in the basements of city halls or in dark and unattractive quarters elsewhere. In some instances they are on the business street of the community, but are not the type of office that attracts favorable attention from the public. Lighting is frequently poor, windows are not washed, the barest minimum of furniture and equipment is used.

There are very few water works offices in which it is convenient to get a drink of water. Surely the product which is being handled by the utility should be readily available in the water works office. An attractive bubbling fountain at a convenient location in the water works office would be a real attraction. In one such office in a western state, there is a bubbling fountain conveniently located near the door, equipped with a plastic water meter through which the water for the fountain flows. This transparent plastic meter constantly turning is the source of much interest to those who visit the office. The piping for the fountain is equipped with a valve for reducing the flow of the water for the fountain to a mere trickle, for the purpose of demonstrating to the consumers how little water is required to turn the meter. This regulation is done by one of the clerks when a person comes into the office to register a complaint for a high bill. Such an installation pays dividends in good will with the public.

Water works offices should be conveniently located, readily accessible to the public and should be attractive and well maintained. The addition of cut flowers or growing plants in water works offices are a great credit to the water system, but too few offices use such attractions. Offices should be well lighted, not only for the comfort and convenience of persons employed in the office, but also to improve the attractiveness of the office to the visiting public.

Water works structures are among the most beautiful. Waterfalls, streams, reservoirs, even pumping stations, pipelines and elevated tanks are graceful and attractive objects. Pictures of

A discussion presented on June 14, 1944, at the Milwaukee Conference by Gerald E. Arnold, San. Engr., San Francisco, Calif.

such portions of water systems might well be used to decorate the walls of water works offices, yet in very few offices are there any pictures in evidence of water or related subjects. Frequently the only picture in sight in a water works office is on some advertising calendar. By contrast it has been noticed that the offices of other utilities, particularly power and telephone, are frequently very attractive, well equipped, and comfortable. There is no reason why the water utilities should not have as attractive and well-equipped offices as those of any other utility.

Corporation yards are another section of water works plants which are often unattractive. They are frequently located in the industrial or warehouse districts of their communities and are sometimes the worst-looking plants there. In many instances it has been noted that the corporation yard is surrounded by an old barbed-wire fence, part of which has fallen down, is equipped with an old sheet-iron building painted for the last time in some past era, the yard itself full of miscellaneous piles of water works supplies and equipment. The first thing one notices upon entering the yard is a big pile of junk. I do not know why it is that so many water works men insist upon piling the junk and other discarded material in the center of the yard or right in front of the entrance gate, but such seems to be the practice in many instances. The facilities for use in corporation yards are frequently totally inadequate and lack any sign of maintenance.

Warehouses are often dark, materials are not stacked away in an orderly manner and there seems to be an outstanding tendency to pile equipment and supplies in aisles and passageways, making it necessary to climb over this material in order to get through the warehouse. Corporation yard offices are frequently worse than the business offices. One often notices an old battered desk in the corner, provided for the foreman, on which is a stack of work orders gathering dust through the years. Materials stored outside in the yards are often scattered around instead of being stacked up in a neat fashion. Cars and trucks are parked at random in the yard, and there seems to be little orderliness about the business carried on there.

A corporation yard should be a credit to any utility and a water works superintendent should be proud to show visitors his yard. In one western city the corporation yard is composed of the buildings formerly used for the stables of the street department. When the street department was motorized, the old stables were turned over to the water department for a corporation yard, with the probable command that "it's good enough for the water works." The facilities are obviously inadequate and no credit to the utility. Why should a water works operator have to stand for such procedures? The water utility is one of the most important businesses in the community and the facilities with which the utility has to operate should be commensurate with its importance in community affairs.

The use of loading ramps, truck level platforms, and other facilities would assist in reducing the manual labor involved in operating a yard. An overhead trolley system with a chain hoist or crane would pay for itself in a short time, in the saving of manual labor used in handling heavy water works equipment. In a few cities it has been noted that the corporation yard is modern, adequate, well equipped and well

maintained, but the number of these is too few. Even in these cases, the other utilities, particularly power and telephone, have much more adequate corporation yard facilities than the water works.

The subject of public relations is somewhat neglected by the water works industry. It is suggested that thought be given to the possibility of advertising the water system through distribution of printed matter, through newspaper and radio publicity, through appearances of water works officials before service groups, school groups and other community organizations. The water works industry can be, and should be, lifted to a high standing in the communities of the nation, but it will be lifted to this level only if the water works profession determines to accomplish this end.

Erratum

Membership Directory. Jour. A.W.W.A., **36**: 133 (No. 10, Part 2) (1944).

An omission was made in By-Laws Article VII, Section 5, in the Constitution and By-Laws of the Association, published in the 1944 Bi-Annual Membership Directory. The text as it appeared in the 1942 Directory, page 16 of the Constitution and By-Laws, was correct and included the material below. The complete section should appear as follows:

SECTION 5. Any member of the Association who resides in a locality which is not included in the territory embraced by an existing Local Section, may upon written request to the Board be included in the membership of any Local Section. The Secretary of the Association shall notify the Secretary of the Local Section of the enrollment of the member.

Whenever a new Local Section is formed or an existing Local Section has its territory extended which will include in its territory the locality where such member resides, he shall automatically be included in the membership of such Local Section.

Should a member of the Canadian Section desire to participate in the activities of any other Section more conveniently located, he may do so under the following conditions:

a. He shall make application to the Secretary of the American Water Works Association who shall transmit his request to the governing bodies of the Sections concerned. If the latter approve, then the member shall be allowed to acquire membership in the additional Section.

b. He shall then be eligible to vote and enjoy all the privileges of both Sections, and may hold office in both Sections, but not simultaneously.

c. Any allotment of funds from the Association on his account shall be paid to the Section in which territory he resides. By arrangement between the governing bodies of the Sections involved, such allotment may be divided between the Sections.

d. If a change takes place which makes his own geographic Section equally accessible, membership in the adopted Section shall cease.

Utilization of Ground Water in a Postwar Program

By H. Howard Cranston

GROUND-WATER supplies in the past generally have been looked upon with a great deal of uncertainty. Such statements as, "Anything below the surface of the ground is a raw gamble," have frequently been made by people unfamiliar with the true facts. This uncertainty, or "gamble" as some people refer to it, can be controlled to a substantial extent. Anyone undertaking a ground-water development can solve many of the unknowns of a ground-water source of supply and the so-called element of gamble can be largely removed.

It is true that there have been failures in ground-water projects when geologists or engineers were employed. But these failures emphasize the facts that the professions of geology and engineering are broad and that only those thoroughly trained and familiar with ground-water problems should be expected to carry on the work successfully.

In spite of a definite demand for ground water throughout New York State, only a few published reports dealing with ground water within the state have been made available to the general public. The investigation of ground waters of Long Island by the United States Geological Survey in co-operation with the state of New York and Nassau and Suffolk Counties; the investigation in Monroe County by the U.S.G.S. in co-operation with Monroe County; together with the New York State Museum bulletin on "Ground Waters in Allegany State Park" serve to emphasize the need for further investigations of this kind.

As a whole, ground-water sources of supply have been minimized in the past. When a community or city decided to acquire additional surface-water supply, the usual procedure was to employ an engineer to make accurate surveys and careful studies. Unfortunately, this has not been so with ground-water supplies. The usual procedure was to employ the well driller living closest to the project and to start drilling a hole without consideration of geology or proper well methods. Usually the well driller was told by some self-appointed individual to keep drilling until he "struck water." Due to the well problems involved, the average well driller in the past and many today are not capable of securing the maximum yield from water-bearing formations, particularly sands and gravels. Consequently, many wells have been drilled through water-bearing sands into the underlying bedrock with poor results. This practice has

A paper presented on April 28, 1944, at the New York Section meeting, Utica, N. Y., by H. Howard Cranston, Henry H. Cranston & Son, Fredonia, N.Y.

resulted in the unwarranted condemnation of areas capable of yielding good ground-water supplies. Even today there is an inclination on the part of many people toward surface supplies primarily because the surface water can be seen. From the proper use of certain geological information and the interpretation of test borings, ground waters also can be "seen" indirectly. We all know that we cannot see the roots of a tree, but we all know that they are there and must exist. Likewise, this is true of geological information when properly applied.

Three conditions must exist for the proper utilization of ground waters. First, the water itself must be present. The source of ground water is precipitation which reaches the earth in the form of rain and snow. All parts of New York state normally receive an average annual precipitation in excess of 30 in. While only a small part of this total precipitation is available for seepage or ground water, it can be shown by the following brief calculation that large volumes of water do exist for ground-water supplies. An acre, which is approximately 209 ft. on each side, is used here for illustrative purposes. One inch of rainfall on one acre provides a total volume of water in excess of 27,000 gal. Based on a 30-in. annual rainfall, 810,000 gal. will fall on this one acre during the year. Allowing a 20-per cent seepage factor, 162,000 gal. should be available during the year for ground-water utilization from this small unit of one acre. This is enough water to meet the demands of a village of 2,000 population for one day.

Second, porous media must exist that will receive, transmit and store the water below the ground surface. The best natural medium is sand and gravel. Practically all of New York State was covered by a glacier, which left large deposits of such material. These sand and gravel deposits, by nature of their deposition on or near the surface of the earth, readily receive, in a sponge-like manner, the precipitation as it falls on the surface. The deposits are also continuous, having been reworked in many areas by the waters of glacial lakes and streams. This permits large quantities of water to be transmited into and through the sand and gravel strata. The sand and gravel formations, because they are loose and unconsolidated, also afford immense storage volume for ground waters. While the voids or porosity of sand and gravel deposits vary considerably due to differences in composition, an assumption of 25 per cent porosity should be about right for the usual type of water-bearing sand and gravel deposit in New York State. Again referring to the one-acre plot for illustration and assuming a uniform sand and gravel bed 10 ft. thick with a porosity of 25 per cent underlying this plot, a storage volume of approximately 819,000 gal. is provided in this small unit of one acre.

Third, to utilize this ground water some means must be provided by man to obtain the water from the natural deposits. Usually this can best be accomplished by the use of a well. While Webster's dictionary defines a well as "a pit or hole sunk into the earth," there is much more to a well than just a hole. Many factors must be considered in the proper construction of a well. Details of construction vary widely. The natural conditions existing at a particular location cannot be changed but the details of well construction can and should be changed

to meet best the natural conditions present. In most localities throughout the state, the double-cased gravel-filter type of well has been found adaptable for the development of water-bearing sand and gravel formations. With this type of construction, the natural sand and gravel is removed and select filter gravel introduced around the well screen. This tends to give greater intake area to the well with resulting larger yield and higher pumping elevation.

Geological conditions in New York State are favorable for ground-water supplies. With practically all of the state having been glaciated, sand and gravel formations are numerous. They are the best source of ground water, both as to quantity and quality. Many preglacial or "buried" valleys which form structural traps for ground waters also exist in the state. In late Tertiary time, the streams carrying the precipitation from the land eroded stream channels and valleys in the bedrock. These streams were equal to or greater in number and magnitude than the present-day streams, since precipitation at that time was much more than it is today. The glaciers, besides leaving a relatively thick layer of sands, gravels and clays over most of the land, also filled in these old valleys. Some of these valleys were not completely filled and today their location can be accurately determined by brief inspection. Others, however, were completely filled and obliterated on the surface so that detailed geological field work is necessary to determine their location accurately. Due to the low elevation of these old valleys in respect to the surrounding topography, the precipitation naturally flows into them, usually both as runoff and as seepage. Also, the valley fill is of porous composition as it is made up of sands, gravels and clays which were generally deposited by water at the face of the ice instead of in the ice sheet itself. The water in these valleys frequently travels comparatively long distances and is under artesian pressure. A pressure at the well head of 75 psi. has been noted on one well located in a preglacial valley in the central part of the state. From another well in a preglacial valley in the western part of the state, a natural flow in excess of 500,000 gpd. is obtained.

Anyone considering the installation of a ground-water supply should first make definite plans of procedure, including detailed geological and engineering studies. The studies should include the review of any published ground-water reports covering the area under consideration. However, as previously noted, only a few published reports pertaining to ground-water investigations in New York State have been made available to the public to date. It is hoped that more ground-water reports will be made available to the public in the near future by the state geological department or other suitable agencies. Undoubtedly the beneficial economic results derived from such investigations would far outweigh the costs.

After reviewing the published reports, if any, the geological formations underlying the region should be carefully studied, especially the sand and gravel beds. The surface of the bedrock should also be studied with particular emphasis placed on the preglacial drainage pattern. All existing wells should be plotted on a suitable map and available data concerning each well recorded. Care should be exercised in compiling such data so as to secure *reliable* information, since many

well logs are given from memory. Where there is any appreciable depth to bedrock and the existing wells derive water only from the bedrock, water-bearing sands and gravels may exist that have been cased off by the well driller of limited experience due to the mechanical problems involved. Water-bearing sands and gravels frequently have been erroneously reported as "quicksand." The scope of the studies conducted will depend largely on the magnitude of the particular ground-water project under consideration. The studies may cover an area of only part of a township or perhaps a county or even a portion of the state.

Providing that the preliminary studies indicate the existence of geological conditions favorable to the development of the desired ground-water supply, test borings should be sunk at strategic locations. Generally at about this stage of the project someone wants to determine the locations by use of the peach twig or "forked stick." Investigations of the divining rod by the U.S.G.S. have been fully described in Water Supply Paper No. 416, and its use is not recommended. However, there is a definite need for instruments such as the seismograph, which has been used in the determination of subsurface structures and rock contours.

Test borings are very important as the success or failure of the project depends on the data disclosed by them. Test borings should be made only by a competent well driller who is thoroughly familiar with ground-water development. Representative formation samples should be taken and an accurate log made of the strata encountered. Pumping tests of water-bearing formations should be conducted and water samples taken for determination of basic quality. The effect of pumpage can be noted in observation holes and in any surrounding wells. Dyes can be introduced into the ground to determine water flow and the movement of the water. All data pertinent to the project should be recorded in field books. There cannot be too much detailed information in a ground-water study.

If the results of the test boring investigation are favorable, the installation of the service or permanent wells should be made after careful study of the natural conditions disclosed and all other factors involved. Care should be exercised not to exceed the "safe yield" of the formation developed with the resulting dangers caused by drawing on underground storage over an extended time. Treating equipment, if required, can be designed from the analyses of water obtained from the test borings. Accurate pumping tests should be made by means of temporary test equipment to determine accurately the hydraulic characteristics of the well. Permanent pumping equipment can then be designed to meet the conditions of well and system most effectively and efficiently. Many well pumps today are, due to guess work, operating inefficiently against induced heads by throttled discharge.

It is highly desirable to have the well contract so written that both the test borings and well drilling are included in one contract. Much better installations result when this is done. While many oil and gas wells are drilled on the footage basis, this type of contract is not particularly adaptable to wells for municipal water supply. The "water-production" type of contract in which the well driller is paid for the water that is actually produced has

advantages to the sponsor of the project. As a rule the project has more chance of success and the work is conducted more efficiently.

According to the latest bulletin of the New York State Department of Health, which was printed in 1940 and which gives data on public water supplies in the state, there are 800 public supplies, 417 of which are derived from ground water. These 417 ground-water supplies serve slightly more than one and one-half million people. While ground waters are particularly adapted for the use of small municipalities, they are not necessarily limited thereto. Recently, several important and relatively large ground-water supplies have been constructed. Notable among these was a large army camp supply in excess of 3 mgd. having a hardness of less than 50 ppm. Early in 1944 a city of about 90,000 population located in the east-central part of the state placed in operation a new ground-water supply.

Ground waters are generally harder than surface waters, but many well supplies have been constructed throughout the state yielding waters of less than 100 ppm. hardness. Many of the harder well waters are derived from the limestones and calcareous shales of the bedrock. Evidence has been observed on one project in the western part of the state suggesting "natural softening." When water of a known hardness was passed through a sample of water-bearing sand that had been obtained from a test boring, the water was appreciably reduced in hardness.

In summation, some of the advantages of a ground-water supply are:

1. The initial cost of installation is generally much less than on other sources of supply.
2. The operating costs are low.
3. The water produced is safe and frequently it is not necessary to chlorinate it.
4. Filters are seldom necessary as the water is clear and without turbidity.
5. The temperature of the water, regardless of season, is generally 50° F. or less.
6. The chemical composition, while generally harder than surface supplies, tends to be more constant without seasonal fluctuations.
7. The pumping plants are compact and require small surface area.

The chief disadvantage is that geological conditions are not everywhere as favorable for ground-water development as in New York State.

Postwar Planning of Water Works in New York State

By Earl Devendorf

NEW YORK State, while making every possible contribution to aid the national effort in bringing to a successful conclusion the present war, has also given thought to the problems and events which will follow the armistice. Various measures have been taken toward the prevention of unemployment and for the prompt remedying of any unemployment that may arise. To this end the state has adopted a policy of economy in state expenditures, deferring as much capital expenditure as possible to the postwar period; it is accumulating funds in the state treasury to avoid increased taxes at the close of the war and to make available funds for postwar state construction; and state aid has been authorized to assist municipalities in making plans now for needed projects to be constructed at the close of the war.

For a better understanding of the procedures and policies of the New York State Postwar Public Works Planning Commission, it is desirable to describe briefly the makeup of the commission and the laws under which it operates. The commission is comprised of seven members; the chairman being the director of the state budget and the other members being heads of other state departments and members of the legislature. The office staff consists of an executive secretary, assistant chief engineer, field consultants, economist and the usual assistants, clerks and stenographers.

Legislation

Legislation was passed in 1942 carrying an appropriation of $500,000 to provide for financing the activities of the commission. The 1943 Legislature increased the amount of funds available for postwar planning by an additional $3,000,000 and the 1944 Legislature increased this by another $4,000,000.

State Legislation

Chapter 660 of the Laws of 1942 as amended in 1943 created the State Postwar Public Works Planning Commission. It has assigned to this body, among other duties, the responsibility of co-ordinating plans for postwar construction by the various state agencies and of allotting funds for the preparation of plans for certain state projects and for assisting municipalities of the state in the preparation of plans for postwar projects. It has authorized the commission to assist municipalities in planning postwar projects to the extent of defraying 50 per cent of the cost of preparing plans, specifications and estimates of approved projects in an

A paper presented at the Milwaukee Conference on June 15, 1944, by Earl Devendorf, Asst. Director, Div. of Sanitation, State Dept. of Health, Albany, N.Y.

amount not exceeding 2 per cent of estimated cost of the project, upon certification of the fiscal officer of the municipality that a like sum has been made available by the municipality for such purposes. The commission is not authorized to make any grants for construction.

Local Legislation

Chapter 696 of the Laws of 1943 amends the general municipal law and the local finance law in relation to financing of plans for postwar projects. This act authorizes each municipal corporation, school district or district corporation to issue notes to be denominated "Capital Notes" for expenditures during the fiscal year, for its share in the cost of the preparation of plans for postwar projects, to the extent that such expenditures are not provided for in the annual budget. There is, therefore, no reason for delay in the submission of applications for state grants on the part of the municipalities of the state for the preparation of plans and specifications for worth-while and needed postwar projects.

Policy

In considering applications for municipal postwar public works construction projects, the state commission has declared its intention and desire to cooperate as fully as possible with all New York State municipalities and districts to the end that the purpose of the act will be carried out, namely, that detailed plans and specifications for needed public works projects will be prepared now and will be available for use in the postwar period. The commission is not authorized to give grants or aid in connection with engineering work already done.

The commission has adopted the policy of making grants only to municipalities for the preparation of plans for projects, the cost of which does not exceed their borrowing capacity as determined by the state comptroller. The state superintendent of public works requires that the preliminary plans and estimates of cost be in sufficient detail to permit a check of the estimated cost of the items of work included in the project. The estimated cost of the project as checked by him is based on the average 1940 construction costs.

Among the problems that have arisen have been the differences in estimated cost of projects as originally estimated and the costs submitted with the preliminary plans as determined after an engineering study and analysis of the project. The amount of the state grant is determined by the superintendent of public works after an analysis of the preliminary plans and engineering report on projects which have been approved by the commission; whereas the estimate of cost submitted with the application may more properly be termed a "guess" estimate as it is arrived at without the benefit of any engineering study or analysis. The commission has adopted the policy, when making the final grant for detailed plans, of adding or subtracting, as the case may be, any deficiency or excess in the preliminary grant resulting from differences in these estimates of cost.

Procedure

The "Postwar Public Works Municipal Handbook" (prepared by the New York State Postwar Public Works Planning Commission in conjunction with the New York State Department of Public Works) gives an

outline of procedure to be followed by municipalities and districts when applying for state grants for the preparation of plans of municipal postwar projects. The essential features of the procedure may be briefly summarized as follows:

A limit of 2 per cent of the estimated construction cost is the maximum amount the commission is authorized to contribute to municipalities for the cost of design. This sum is to be matched by a similar amount contributed by the municipalities. In addition, the commission, upon recommendation of the state superintendent of public works, may, in its discretion, allocate such additional sum or sums as it may deem necessary to pay the cost of test borings or other extraordinary expenditures which it may deem desirable.

In making application to the commission a brief description of the proposed project is required with its estimated construction cost and a certified resolution indicating that the locality will provide its share of the cost of the plans. Upon receipt of applications they are reviewed by the commission and, if deemed desirable, are referred to the state superintendent of public works who analyzes the reports and submits his recommendation to the commission. If a favorable recommendation is made by the superintendent of public works he will indicate the allocation that should be made for the state's share of cost for preparing the preliminary plans and estimates. This cannot exceed 0.5 per cent of the estimated construction cost. The commission then acts upon those projects which have been recommended favorably by the state superintendent of public works. In other words, without the approval of the state superintendent of public works, favorable action by the commission is precluded.

On approval of the preliminary plans and estimate the commission will determine the amount of the grant for the final plans and specifications. This amount, together with that allowed for preliminary plans, cannot exceed 2 per cent of the revised estimated construction cost.

Payments of grants for both preliminary and final plans in amounts over $1,500 are made in three installments, the first when plans are 50 per cent completed, the second when they are 100 per cent completed, and the balance on their approval by the commission. In the case of grants of less than $1,500 only one payment is made, on approval of the plans by the commission. One blueprint copy of the preliminary and final plans, specifications and cost estimate will be filed in the office of the state superintendent of public works.

The Division of Sanitation of the State Department of Health is working in close co-operation with the Postwar Public Works Planning Commission and the state superintendent of public works in the review of applications for postwar sanitary projects submitted to the commission for consideration.

One of the functions of the Division of Sanitation has been to encourage the installation of needed sanitary public health improvements. In this connection it has maintained for many years a list of worth-while needed projects that might be undertaken.

A review and study of needed sanitary projects in connection with postwar planning has been made by district engineers and many conferences have been held with local municipal authorities at which time the submis-

sion of applications to the State Postwar Public Works Planning Commission for financial aid for the preparation of plans has been stressed. This has resulted in the preparation of an up-to-date classification of needed sanitary projects, arranged according to their necessity, urgency and desirability. This information has been furnished to the Postwar Public Works Planning Commission and the State Department of Public Works.

In connection with a review of applications referred by the commission to the superintendent of public works, the Department of Health has worked out a procedure to assist in this review. This involves a joint field inspection and survey by the district engineer of the State Department of Public Works and the district engineer of the State Department of Health, each of whom separately reports the results of his findings to the respective departments. Based on these reports, recommendations are made to the commission regarding the necessity, urgency and desirability of the projects under consideration.

Water Supply Projects

One of the most important types of postwar projects that has been recommended is that of needed public water supply improvements. This recommendation of the State Department of Health has been received favorably by the superintendent of public works and the Postwar Public Works Planning Commission with the result that many such applications have been approved and allocations of funds made for the preparation of detailed construction plans.

As of Oct. 1, 1944, 123 water supply applications, with a total estimated cost of $10,324,198, had been received by the commission. Sixty-eight of these applications, with an estimated cost of $6,177,688, have been approved by the commission and work is now under way on the preparation of plans for the water supply projects. Fifty-five applications, having an estimated cost of $4,146,510, are awaiting action by the commission.

In a majority of cases, consulting engineers have been engaged by the municipalities to make the necessary field studies and draw up the plans and specifications in accordance with the requirements and procedure of the commission. In some instances the regular engineering staff of the municipality is preparing the plans, particularly where the types of projects are not complicated.

Conclusion

The New York State Legislature has adopted a sound policy of planning and financing for both state and municipal construction of needed projects for the postwar period. By making state grants to aid municipalities in the preparation of plans for such projects, it has provided a stimulus for action by the municipalities, which are preparing plans now so that construction can be started immediately at the close of the war.

Postwar Water Works Construction in the Southwest

By Homer A. Hunter

THE great Southwest is on the threshold of its greatest over-all development era. This section has for many years enjoyed a leading rôle in agriculture, cattle-raising and dairying and in the production of vast quantities of oil, sulfur and other mineral products.

Until comparatively recently, little, if any, attempt has been made to process locally, on a commercial basis, either the agricultural or the raw mineral products. The manufacturing of the finished product from these raw materials has been left largely to those areas farther east, where industry has already been highly developed. But this picture is changing rapidly. Spurred by the impetus of wartime production, hundreds of manufacturing plants, both large and small, have sprung up throughout the area, many of them being built as close as possible to the various sources of essential raw materials. Practically every kind of plant imaginable is now at the full peak of production. Constructed in record time and equipped to do a specific job, many of these plants, established within the past few years, have not only met, but exceeded production quotas and schedules.

A paper presented at the Milwaukee Conference on June 15, 1944, by Homer A. Hunter, Supt., City Water Works, Dallas, Tex.

The industrialization of the Southwest has indeed already begun. But what we have seen is only the beginning. The next decade will, in all probability, see a more rapid growth and development along these lines than has ever been witnessed anywhere else in the United States. The industrialization program of this area has been advanced at least 20 to 30 years.

Processing plants are already producing great quantities of gasoline and other refined petroleum products. A great deal of aluminum and magnesium is also being produced, while clothing and other finished products from cotton and wool are being turned out in increasing quantities. Paper mills have been established to produce paper from native timber. A large iron smelter is almost completed and the construction of a steel mill is scheduled to begin very soon. A great many other minerals such as asphalt, coal, salt and sulfur are present in abundance in the raw state and are now being processed in the Southwest.

Water Resources

In recent years the rapid shifts in urban population, brought about through the rapid growth of industry occasioned by the war effort, have demonstrated the importance of water supplies. It is a pertinent fact that

water resources are definitely a limiting factor in the industrial development of the Southwest. There are hardly any streams that have a sufficient minimum flow to take care of the needs of large industries. A comprehensive water conservation and control plan must, therefore, be worked out. While the total annual flow of the streams is sufficient in volume, it is necessary to impound the flood waters so they can be utilized during seasons when the natural stream flow may be negligible.

There have been many instances where it has been found that existing water resources in certain cities have been insufficient to supply demands of industries seeking new plant location. To cite a single instance, there is one industry operating in Texas which requires more water daily than does the city of Houston. Consequently, this particular industry was compelled to develop its own source of water supply.

Plans are now in the process of preparation for a $100,000,000 project which contemplates the full and complete use of the Trinity River in Texas. This project embraces extensive plans for soil conservation throughout the entire watershed—flood control reservoirs and levees, conservation reservoirs and canalization of the river from Dallas and Fort Worth to the Gulf of Mexico.

A number of cities have been hard-pressed lately to supply even present demands for water. Some of these increased demands have been created by the establishment of war industries, but in other cases, the situation has become acute because the communities have not kept pace in this regard with their normal community growth. All such situations have, of course, been aggravated by the necessity for stopping all new construction because of materials and manpower shortages. Many millions of dollars will have to be spent as soon as practicable in order to catch up on deferred maintenance and construction work, and many more millions will be required in the construction of improvements to keep ahead of this industrial growth.

Typical of the growth of the Southwest is the interesting fact that, whereas from 1890 to 1940 the population of Texas increased 287 per cent, the water demand increased during the same period more than 7,000 per cent.

Postwar Planning

Postwar planning must, of necessity, become a vital part of any forward-looking program affecting the life and future progress of our nation. It is the solemn obligation of a responsible contemporary citizenship to meet the challenge *now*—to maneuver toward an intelligent approach to the problems already confronting our cities, towns and communities. This obligation cannot be side-stepped or passed on to the next generation; it cannot be ignored, or even minimized, without danger of the gravest consequence to our established institutions. Leadership, imagination and enthusiasm will be needed to develop and carry out any postwar planning worthy of consideration.

Seemingly, an attempt has been made by some to surround postwar planning with an aura of mystery. The intimation has been that postwar planning can become a sort of postwar panacea—a cure for all the evils which may arise at some future date to plague and bedevil the most forward-looking communities. There is, or should be, no mystery about postwar planning. Neither is there any good reason to

consider it as separate or distinct from the ordinary, normal long-range planning, except that its actual consummation must be definitely deferred until after the cessation of hostilities.

Every community, in order to insure an orderly development and growth, must have a comprehensive plan, which must be worked out in considerable detail, must look ahead for a period of years and must include all functions of the local government. Community planning of this sort is merely applied common sense, for without a long-range view and a definite plan of action, the people of a community would be handicapped in determining the possible cost of needed improvements, and would thus find it difficult to arrange an adequate financing program in advance. In any haphazard procedure, costly mistakes would be made. The planning and programming of possible improvements insure the achievement of an ultimate co-ordinated development and make for economy in the attainment of any desired goal.

Many public improvements, already included in a city plan and normally scheduled for construction during the past three or four years, have had to be deferred until a more favorable material and labor market is available. Blueprints for such deferred public improvements may now be rightfully labelled "Postwar Plans" and shifted to another file for future consideration.

Planned public improvements, contemplated now for execution during the postwar period, will take into account the postwar labor situation, and with proper handling, can help very greatly in taking up the slack. Were it not for this one factor alone, planning for postwar construction would differ very little from any other type of long-range planning which might be found necessary now or later. Therefore, the situation must not be considered from any panicky viewpoint. Nor must the sense of values or proportion be lost by regarding postwar planning as too stupendous an undertaking or too complex for solution.

Postwar Water Works Planning

Chief place among the "musts" for any community to consider, if it is to survive, is its water supply. No city or town can survive for long unless it is provided with an abundant supply of pure water for domestic, commercial and industrial use. There must never be any doubt in the minds of the people of a community concerning either the purity or the adequacy of the water supply. It is now the time to examine, in great detail, all sources of supply, as well as the local treating plants, distribution systems and pumping equipment. Detailed plans should be drawn for additions to any of these facilities which may need reinforcing. It should be borne in mind that criticism for having too many pumps or too large a pipeline is one of the rarest things in the world. No excuses have ever been found, however, which are good enough to explain away the *lack* of adequate equipment or facilities. Every customer feels that it is one of his inalienable rights to have all the water he wants when he wants it.

Financing Improvements

At some period after the war is over it may be expected that there will be an economic depression, the degree of which is unpredictable. Nor can it be determined just when it will occur. Certainly, however, it would be wise to hedge against the strong probability of its occurrence. Local governmental

officials should begin now to build up reserves, which can be used to tide over such a period. It would also be well to begin now to search out new sources of revenue. Some tax experts say that the present method of taxing real estate is not equitable, and that a fairer method of spreading the cost of local government, by distributing the tax load, should be sought. Certainly there is much argument to support this contention. It may be that cities will find it necessary to depend less and less on this original source of income and develop new tax revenue sources through direct charges and fees for services rendered. Definite reductions in taxes on real estate could follow in direct proportion to the levying of specific charges for garbage collection, sanitary sewer service, water, building inspection, sanitary inspection and other services now, or to be provided hereafter through additional facilities. Careful study of these problems should be made now to avoid financial embarrassment of local governments confronted later with postwar problems which money alone might cure.

Along with this economic analysis, therefore, due consideration must be given to all possible sources for financing postwar construction. It is a foregone conclusion that the finest plan possible to conceive would be just so much paper unless it can be adequately financed. Plans should never be based on the expectancy of obtaining grants of money from the United States government. The popular habit and general practice of reaching into the federal treasury for money with which to carry out local improvement programs is fundamentally unsound. In a democracy, where a fight rages constantly to retain the advantages of free enterprise, any tendency towards treasury raiding should certainly be resisted. Otherwise, it may be discovered that the much desired freedom has been lost.

Federal Government Planning and Financing

It is a generally accepted fact that a banker who lends money has considerable to say about what use is made of it. The attitude of the federal government is no different in this regard, and some bureau officials exhibit strong tendencies along the same lines. Consequently, if loans or grants are accepted by local governmental units from the federal government for use in construction of local public improvements, it should not be surprising if the federal governmental agencies insist upon exercising considerable control over these improvements.

Someone has said that "proper planning starts at the grass roots." Certainly all planning of local improvements should be done by the people who are themselves close to the problems to be solved. The details cannot possibly be worked out by folks in Washington who are not intimately acquainted with local conditions. Of course, national policies will continue to be formulated and adopted at the nation's capital, but these policies should be influenced directly through information gathered from every available source throughout the country; from each county and state in the nation. It is only in this manner that a true picture can be obtained that will be a reflection of actual conditions.

Apathy or indifference on the part of local governments will naturally invite suggestions from Washington, if not actual insistence and interference. The big danger in bureaucratic suggestion or domination is that the planner, far

removed from the problems to be solved, may be influenced too much by minority groups close at hand who can be more vocal than the home folks, and who can sometimes make a louder noise than the majority; or else they may act unwisely because they lack detailed information on the subject.

Planning by local communities should never be influenced by the thought that some outsider may have to approve the details. The one sure way to remove this influence is for the community to determine, at the outset, that so far as it is humanly possible, it will pay its own way and that it will no longer depend on Washington. Such planning brings government home to the people, where it belongs. It encourages a return to original principles, promotes self-confidence and initiative and restores individualism and independent action.

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Financing Water Works Improvements in the Pacific Northwest

By G. B. Schunke

THE Pacific Northwest, which is comprised of the states of Idaho, Oregon and Washington and covers an area of 250,000 sq.mi. is bounded on the east by the Rocky Mountains and on the west by the Pacific Ocean. The Cascade Mountains, running north and south, divide the territory into the semi-arid eastern section and the western section, abundant in moisture.

Both sections of this vast area have enjoyed a steady growth, although the western section has a population three times that of the eastern section due largely to an excessive concentration of urban population on Puget Sound and the area surrounding Portland. This has been severely aggravated by the industrial expansion of the last four years. Portland has become the foremost shipbuilding city of America and Seattle has become famous as the home of the Flying Fortress. It is estimated that 50,000 persons have migrated to the Pacific Northwest in the last four years, increasing the population by at least 15 per cent and in certain communities up to 50 per cent or more.

As in other parts of the United States, the water utility is predominantly municipally owned and for all practical purposes financing of water works improvements means public financing and will therefore be discussed from this standpoint only.

In the larger cities of Portland, Spokane, Tacoma and Seattle, as well as in many smaller communities, the water systems began as private enterprises, but because the business was not sufficiently remunerative and new capital could not be raised in sufficient quantities to meet the needs of the several communities, public ownership became inevitable.

Generally speaking there are four methods by which capital is procured for new extensions or construction in the Pacific Northwest.

1. General bond issue guaranteed by the city.
2. Utility or revenue issues pledged by the city.
3. Investment of current surplus in new extensions.
4. Local improvement assessment, by which the abutting property is charged for the construction of the distribution system.

General Lien and Revenue Bonds

The issuance of general lien bonds pledged by the credit or taxing power of the city is rapidly becoming obsolete.

A paper presented at the Milwaukee Conference on June 15, 1944, by G. B. Schunke, Asst. Supt. of Water, Seattle, Wash.

The general credit of the city is required for so many new functions that limitation of general indebtedness precludes this method of financing for water extensions. Public playgrounds, auditoriums, air fields, overhead grade separation and public hospitals are only a few of the things which the public did not provide a generation ago, and since water systems are properly considered to be self liquidating, general lien bonds are no longer in vogue. Therefore, new extensions are now financed by revenue or utility bonds issued by the corporate authorities pledging the revenue as security for new capital. In other words, the utility must stand on its record as a going concern and can no longer hide behind the cloak of a general tax levy.

In order to provide new capital the water plant must show a consistent ability to pay operating and maintenance expenses, to pay fixed charges and to set aside sufficient revenues to pay off the bonds at maturity. To do this successfully there must be a stability and continuity of business management, divorced from political control.

The statutes of the state of Washington provide that utility revenue bonds are a *lien* against the *revenues* of the system *only*. They may be issued for a term not exceeding 30 yr., at a rate not exceeding 6 per cent.

Revenue bonds may be refunded at maturity, but the general practice is to provide for serial payment so that the debt is extinguished when the last bond falls due. This type of bond has proved its actual superiority over general lien bonds because in times of depression taxpayers will defer making payment of their property taxes but will pay their water bills to avoid discontinuance of water service.

Any solvent public water utility has the added advantage of securities being tax exempt insofar as federal taxation is concerned. This is an enormous benefit, reflected in the current prices paid for bonds. Whereas the federal government is paying 2.5 per cent on long-term obligations, any solvent public water utility with a good record can obtain funds for 2 per cent or less.

Investment of Surplus

It is often said that public service should be rendered at cost. Providing for operation, maintenance, interest charges and depreciation covers the costs of a utility, but unless the rate structure is sufficient to provide for a portion of the capital expenditure required, the utility is headed for grief.

A book entry charging depreciation without setting aside tangible reserves is mere subterfuge. Unless capital liabilities are reduced or new construction out of earnings provided to the extent of the amount charged to depreciation, this item can have no meaning. Any plant that is fortunate enough to have no capital debt should set aside, for the purpose of future extensions, cash reserves at least equal to the amount charged off as depreciation, so that the physical assets of the water system plus cash reserves always equal the original cost.

The last few years have seen the financial conditions of water plants vastly improved because of increased earnings and less opportunity of spending through lack of materials and manpower. Paradoxically, as the national debt has increased, that of states, counties, cities and public utilities has decreased.

But there is no reason to believe that after the war is over the public will give its municipally-operated utilities

the privilege of bonding the utility excessively for future extensions. Part of this capital should be raised from the net income or profit that the utility may be able to accumulate. Fortunately this is being done in the larger communities of the Pacific Northwest.

Local Improvement Bonds

Oregon, Idaho and Washington laws permit cities and towns to assess property for distribution mains. In the state of Washington the legislature has provided local improvement statutes granting authority to various cities, towns and water districts to create local improvement districts for the purpose of installing water mains and hydrants, the cost of which is charged to the abutting property. This assessment may be paid in cash or permitted to run for ten years at 5 per cent, one-tenth of the principal being retired annually.

These local improvement bonds are a lien against the property served and the bondholder looks to the property for payment.

Since 1927 the bondholder has been further secured by a guaranty fund which the city is obligated to create, from which all unpaid local improvement bonds are paid when past due. This has had the effect of making these local improvement bonds an attractive, tax-exempt investment.

The distribution system of any community represents a very substantial part of the entire cost of the project, and if the mains are provided for by the property owners, it should be reflected in lower water rates. It also has the merit of making the vacant property pay its just proportion of expense so that the present water consumer is not saddled with the whole cost.

This policy has been in effect in the state of Washington for many years, and since the present property owners have paid for their water mains it is not likely that any other method of financing distribution mains will be put in operation.

This method of financing the cost of the distribution system eliminates any favoritism to one part of the city over another in the matter of water mains and hydrants. It also prevents the installation of mains before there is need for same, for the law provides that, if 60 per cent of the affected frontage protests, the improvement cannot be legally consummated.

Conclusions and Comments

The acid test to be applied in the creation of new debt by issuing bonds hypothecating the revenues of the plant and mortgaging its future income may be tersely stated as follows:

1. Will it increase the margin of safety or capacity of the plant?
2. Is the extension not merely desirable but necessary?
3. Will it be self-liquidating, that is, will it pay its way over the life of the bonds and finally liquidate the indebtedness?

The mere spending of money or undue expansion of a water plant without an affirmative answer to these three questions cannot be justified under any circumstances.

There is another phase of public water works financing that offers distinct opportunities for mischief. It is the device of using a part of the revenues of the water utility for other municipal purposes. Sometimes this practice is called diversion of funds.

More often an additional tax for sewer purposes is levied, based on the amount of water consumed, and the water department is used as a collection agency. Or a tax is levied on the water consumer based on the size of his bill or the amount of water consumed.

The reason for this new phenomena in water works financing is, of course, that tax limitation and the many new demands of municipalities require the raising of additional revenue for general purposes.

A municipal water system is a municipal enterprise. There is room for argument whether any of its profits can be legitimately used for other purposes.

The water users are taxpayers although the relationship is not identical.

The degree and the amount of revenues diverted will, within limits, be controlled by the citizens, but it should be emphasized that any transfer of revenues or funds from a water utility that lessens its ability to function adequately and to provide for future financial requirements, is fraught with extreme danger and cannot be justified.

Each community in our area is absolute master of its own affairs. No state commission in Oregon, Washington or Idaho has any jurisdiction over the rates, service, or any other matter pertaining to publicly-owned utilities, other than a uniform classification of accounting prescribed by the state authorities.

Enlightened self-interest would seem to indicate that sufficient reserves should be set aside in times of plenty to provide for needed extensions when materials and manpower are again available.

Now what of the future? Covering a curve of many years the increase in revenues would average 3 per cent (excluding the last four years). How much of the enormous influx of population will remain in this area after the war?

If we knew the answer the blueprinting for the immediate future would be less difficult but, in any event, we have faith in America and particularly in the Pacific Northwest. The future is what we choose to make it.

Balancing the Production With the Sales Record

By A. P. Kuranz

THE title suggests that a definite balance sheet can be developed when comparing the production record with the sales record, and this is true in utilities where production is accurately measured and metered, and likewise every customer's service is metered. In short, a discussion of balancing the production with the sales record seems to take for granted that all customer's services must be metered.

The title further suggests that the subject matter be considered from the financial angle as well as from the plant management side. On the plant management side, the subject is usually referred to as "accounted-for water." More attention has been focused on this subject during the war than ordinarily, particularly from the standpoint of conservation of natural resources. There is still too much evidence that water is "free for the taking" but the conservation of power in any form that is used to deliver this water to the ultimate customer has received the attention of many leaders in our industry, as well as the Government itself. If a savings of 8⅓ per cent of a plant's yearly pumpage could be made, it would represent one month's pumpage in twelve. This, converted into coal, fuel oil, gas, electricity, or any other means of power used for pumping water, plus the savings made in chemicals used for purification purposes, makes quite an important picture. Of course, saving one month's pumpage in a year in order really to save power and materials, would mean that the total saving would have to be accomplished in the elimination of leaks in the mains and service lines. This might not be impossible in many of our systems.

During the last ten or fifteen years the balancing of production and sales has been discussed quite freely and there has been a decided improvement in the procedure. Without calling attention to any paper—there are many good ones—especially those written in the late 20's—the author would like to point out that men of high authority and unquestioned ability and integrity considered any water utility doing a good job if that utility accounted for 75 per cent of the water used. No doubt during the days when these statements were made and substantiated with sufficient proof, not too much attention was paid to the subject of "free water." "Free water" is a misnomer to begin with, and secondly, nearly every utility has a different viewpoint concerning the matter of what customers should receive so-called "free water." Many cities furnish "free water" to schools, churches, charitable institutions, and for various city functions, such as flushing

A paper presented on June 16, 1944, at the Milwaukee Conference by A. P. Kuranz, Mgr., Water Utility, Waukesha, Wis.

sewers, street cleaning, parks, and public buildings. Others measure by meter installations all of these various uses, so referring to the 75 per cent accounted for as being a good figure fifteen years ago would really mean a considerably higher figure if all of these sources of "free water" were measured.

The writer feels quite humble when he thinks of the time and attention given to the vast amount of material that has been developed on this very important subject. For the 11-yr. period, 1928–1938, the writer has come across 81 articles which give considerable thought to this problem. No doubt there are many more that have escaped attention, but when one thinks of the enormous amount of time spent on this subject by the many water utilities in the United States and Canada, it seems that it is not particularly amiss at this time to discuss advancements and improvements made in this very vital matter.

It will be assumed that water is accurately measured and recorded when it leaves the plant, and if the customer's meters are correct in every respect, we might theoretically expect the two to balance each other exactly. However, with a large distribution system, regardless of the size of the utility itself, it must be taken for granted that the system cannot be perfect in every detail; therefore, some losses must be expected. There are three sources of loss after the water leaves the plant:

1. Loss in the main itself, including losses through leaky valves and leaky hydrants.
2. Loss through leaks in service connections and service pipes.
3. Loss through customers' meters through under-registration.

Leaks

The loss that we would expect to find in the main system itself has received the attention of many high-class engineers and utility operators through the years, and a standard has been established which has been accepted up to now as being a maximum of 250 gal. loss per 24 hr. per in. diameter per mi. of main.* Studies conducted by the Cast Iron Pipe Research Association during the last decade have proved, however, that this figure is altogether too high. There is no formula available which will convert the 250 gal. loss per 24 hr. per in. diameter per mi. because there are so many variables to be taken into consideration that each utility would have to develop its own formula. The Cast Iron Pipe Research Association has figures to substantiate the claim that not more than 2 per cent of the water pumped is lost through the main itself. Smaller towns and cities seem to have a larger figure, while larger cities have a smaller figure, and this seems to be due to the fact that the construction of the main

* Mr. Kuranz refers to statement concerning "Leakage," which appears in The (1925) Manual of Water Works New York, A.W.W.A., 1925, p. 293. It reads as follows: "The commonly prescribed upper limit for leakage is an amount, variously expressed, equivalent to 250 gal. per 24 hr. per inch of diameter of pipe per mile."

This figure is substantially higher than that which is found in the A.W.W.A. (1938) Standard Specifications for "Laying Cast-Iron Pipe," Sec. 15.2—Permissible Leakage. This document reads as follows: "No pipe installation will be accepted until or unless this leakage (evaluated on a pressure basis of 150 psi.) is less than 100 U.S. gal. per 24 hr. per mile of pipe per inch nominal diameter for pipe in 12-ft. lengths, 75 gal. for 16-ft. lengths, and correspondingly varied for other lengths of pipe."

is proportionately better in larger cities, on the average. There is no particular point in analyzing this 2 per cent loss except to state that most of it, of course, is lost at the joints or leaks from the main line valves or the hydrant valves. Service leaks are of greater importance for several reasons; first, in the olden days service pipe material was usually steel and sometimes of a rather poor grade and, consequently, after a few years in service developed small leaks. Goosenecks have been discovered to be a source of considerable leakage. There are many variables which cause loss, such as material, workmanship, nature of the soil, and others. When all facts are added up from the many sources, it would seem that service leakage should not exceed 3 per cent of the total pumpage.

Under-Registration

The third source of loss, the under-registration of meters, also has received considerable attention during the last ten years and a decided trend toward better registration is definitely noticeable. The loss of water in the main system, including hydrants and valves and loss in the service pipe has been more or less confined within certain limitations. If a pitometer survey or any other leak survey has been conducted on the mains and service system, and thereafter constant vigilance paid to any leaks developing, one can with reasonable effort keep this loss down to a definite minimum. The under-registration of meters, on the other hand, presents a problem which varies constantly, depending upon many factors. Too often we find services metered with an over-size meter and this in itself presents a definite loss because the momentary demand for water is lower than the meter can efficiently register. Records from many utilities indicate a fluctuation from year to year in the amount of water sold through customers' meters when compared with the pumping station meters, and it certainly can be argued that mains and service losses do not fluctuate greatly; in fact, one would expect mains and service losses to increase rather constantly as time progresses. Therefore, it must be assumed that the variation in the yearly figures must be attributable to the under-registration of meters. This presents a dual problem to the utility management; first is the loss due to high pumpage, and second is the loss of revenue for the unregistered water. Therefore, from the standpoint of all-around improvement, it would seem that the first place to attempt an improvement in balancing the production with the sales record would be to see that the proper-size meter is installed on each service and that by regular repair and maintenance these meters are kept up to their high point of efficiency.

Determining the proper-size meter for the service is a procedure which has received too little attention, yet it can be easily developed by the use of a meter recording device. A new installation may, in the engineer's and architect's specifications, call for a 4-in. meter, yet it has been found many times that a 2-in. meter can amply provide sufficient water with little loss of head. If no definite estimate can be made previous to the installation, the amount of water can easily be determined after the service has been installed and the plant or installation running at its full capacity. This procedure alone will help materially to improve the regis-

tration of meters and, of course, also help the water works' income.

In the 1943 record of 35 of the largest cities with a population of approximately one-half of the total population of Wisconsin, it was found that 80.8 per cent of the water pumped was sold through customers' meters. The cities' reports showed a range of from 24 to 94 per cent. No doubt the low figure indicates that the utility is not 100 per cent metered because the accounted-for figures definitely refer to the ratio between the master meter at the station and the customer's meter on his premises. In these 35 cities, there is no general, uniform method established between the pumpage and the customer's sales, but the Public Service Commission is constantly working toward having all services, regardless of their nature, metered so that accurate accounting can be accomplished.

The Pitometer Co. has done such a great amount of work throughout the entire United States and Canada that their deductions and conclusions have been accepted quite generally. From all literature available, it appears that the maximum amount of under-registration one might expect to find, or to countenance, would be 4 per cent, although there are many cases on record in which the Pitometer Co. has found losses through under-registration of meters to be much less than that figure.

The improvements made on the meter itself during the last ten years have decidedly reduced under-registration, and records are available in many utilities that indicate that meters can be made to register small flows. There are many utilities in sizeable cities which today have developed a meter-testing and repair program which reduces the under-registration of meters to as low as 2 per cent. It is not uncommon for utilities which have several larger customers using water at a rather constant flow to show an under-registration of less than 2 per cent, but again it must be stated that there is no formula which can be applied to all utilities. Four per cent is a reasonable average for a utility doing a good job of meter maintenance.

Summary

Summing up these three sources of so-called unaccounted-for water, we find that the 2 per cent loss that we might expect in the main distribution system, the not-more-than 3 per cent that we might look for in service leaks, and the 4 per cent loss in the under-registration of meters, means that in a 100 per cent metered utility—and by 100 per cent metered we mean that all customers, regardless of their nature, use the water through a meter—we should account for not less than 91 per cent of the water.

This figure might seem to be too high, but the same authorities who ten or fifteen years ago said that 75 per cent of the water should be accounted for, have now raised their estimate to at least 85 per cent, and many of them have a keen suspicion that 90 per cent is not too high a goal for them to reach by practicing constant vigilance and, of course, by eliminating all of the so-called "free water" customers.

The mention of "free water" reminds us again that the conservation of natural resources, with particular reference to prevention of waste of materials used to develop power, has been forcefully called to our attention during this war period. As stated above, one need save only 8⅓ per cent of his yearly pumpage to save one month's supply

of materials necessary to produce power for pumping purposes. This should suggest to the water utility manager or superintendent that even if he were not paid for the so-called "free water" that the waste would be far less if it were measured and the amount of water which was supposedly used were reported to him. It seems to be a trait of human nature that as long as an individual does not have to give up some of his money or services or what-have-you, for something he gets, he will think he is "getting by with something." This notion is very fundamental, and we see it being practiced too often.

Throughout this paper little or no reference has been made to the effect the improvement made in accounted-for water would have on the financial end of the utility. If a water utility sells a higher percentage of its water through customers' meters, the income will naturally increase. Many examples could be cited and the trend indicates that utilities throughout the country are being recognized more and more every day as business organizations. Even though they are municipally-owned, the time is fast coming when the managers and superintendents of water utilities will be included among the bigger businessmen in their communities because if they do their job right, they are not only servicing residences, but commercial establishments, public buildings, and industrial plants as well. In fact, they are no doubt supplying service and furnishing a commodity to more people than any other one institution in their communities.

In conclusion, let me refer to a statement attributed to the late President Theodore Roosevelt, "Every man owes something to the up-building of the profession to which he belongs." As commissioners, managers, superintendents, or engineers of water utilities, let us resolve to balance our production with our sales record as nearly as we possibly can, thereby proving that we are interested in the efficient, well-managed operation of our utilities.

If every utility were so operated, it would be an example not only for the local citizenry, but for the Federal and State Governments as well. We would show just what one group of people interested in serving the public efficiently can do, and our own standing in the community, as well as the standing of our entire Association, would be much improved in every respect.

Water Utility Liability

By Cornelius T. Waldo

THE article by John H. Murdoch Jr. on "The Legal Limits of a Water Supply System" in the August 1944 JOURNAL and the discussion following deal with matters vital to any public utility. Any governmental attempt to impose health or police jurisdiction upon the facilities employed and owned by the private consumer, such as the U.S. Public Health Service Drinking Water Standards' definition of a "water supply system," necessarily raises some question as to the liability of the utility for health conditions upon the consumer's premises and under his control.

However, it is not conceded that a health law or regulation defining a water system for the purpose of enforcing health laws has any effect on the tort liability now enjoyed by the water utilities. Particularly, it may be doubted that a water utility has any interest in or control of "the free-flowing outlet of the ultimate consumer," which assumes a fine physical condition of the ultimate consumer who has long been the subject of public health campaigns. Aside from the intriguing terminology used in the drinking water standard (and leaving unstated the doubts as to its validity) it is believed that the state and local health laws are sufficient to control health conditions on private premises, either by nuisance actions or otherwise.

There have been court decisions imposing liability upon utilities for matters occurring on private premises served, such as permitting a service connection to a *vacant* building to remain open when the utility knew or should have known there was a "free-flowing outlet" operating in the building; or such as pollution cases arising from backflow from an unprotected service to an industrial plant. The defects in such cases are upon private property. As a general rule, as Murdoch states, the liability of the utility ceases at the property line and the exceptions are based upon contract or negligence.

It would seem that the drinking water standard hoists the U.S. Public Health Service upon its own petard, as the responsibility for certifying water systems for interstate commerce would now entail an inspection of the plumbing installations and practices of millions of private consumers. Mere inspection would not afford any guarantee of continued good behavior by the private consumers.

A contribution made by Cornelius T. Waldo, Deputy City Attorney, Los Angeles, Calif., after he read Mr. Murdoch's article (Jour. A.W.W.A., **36**: 865) and before the issuance of State Health Officers' Circular Letter No. 85 (see this JOURNAL, page 1267).

Certainly no water utility should, in its right mind, admit or seek any power to administer police or health laws on the private property of its customers. The extent of the duty and correlative liability of a water utility is to employ reasonable care and diligence, under all of the facts, to provide facilities and operative methods to supply water fit and in sufficient quantity for general consumption and ordinary industrial purposes. As a part of this business, the utility should refuse to serve any consumer whose use or method of use of water does or may cause pollution in the water mains. This is not done as a police regulation but only to perform the duty of a utility as a business.

All utilities are affected by a public interest and may be regulated in their practices by appropriate laws and regulations. But not even the U.S. Public Health Service can take away all the facilities and practices of private water consumers and dump them on the utilities of the country by enacting a poorly conceived and worded definition of a "water supply system." At least, I hope not.

Interpretation of the Public Health Service Drinking Water Standards

THIS statement of policy might well be prefaced by pointing out that many of the difficulties encountered thus far in the application of the 1942 Drinking Water Standards may be attributed to their consideration as engineering specifications rather than as standards. Naturally a standard of measurement or comparison, a model to be followed, should be developed so that progress and improvement may be achieved or stimulated. The 1942 Drinking Water Standards were developed with this in mind. As evidenced by inclusion of the preface to the 1925 Standards in the present edition, and further by the last paragraph of the report of the Advisory Committee, there has been a sincere appreciation by the Advisory Committee of the necessity for reasonable interpretation and the importance of judgment and discretion on the part of the certifying authority. It was not intended that there should be an abrupt change in viewpoint in the application of the 1942 Standards, over that in effect with the former standards, insofar as the application of judgment, discretion and common sense are concerned.

State Health Officers' Circular Letter No. 85, issued by the United States Public Health Service, Sept. 1, 1944, outlining the policy to be followed in interpretation of the Drinking Water Standards adopted Sept. 25, 1942. Republished by permission of the Surgeon General. *See editorial comment on page 1271.*

U.S. Public Health Service Drinking Water Standards

To assist all of those concerned with enforcement of these standards, the following interpretations of certain sections are presented. The interpretations were reviewed by the Special Advisory Committee which drafted the 1942 Standards and were endorsed as consistent with the committee's views by a majority of its membership.

SECTION 2.2. This requirement is intended to be a standard or model to be attained by co-operation of the water works authority, local and state health authorities, and other agencies having jurisdiction.

A reasonable application of this requirement for purposes of certification of common carrier water supplies would be:

(*a*) Strict application insofar as practicable under existing conditions of Sec. 2.2 to collection, treatment and distribution works from the source to the meter or connection to the customer's premises.

(*b*) A sincere effort on the part of municipal, county and state authorities having jurisdiction toward the elimination of sanitary defects and health hazards as defined in Secs. 1.4 and 1.5. from the water distribution system within the customer's property.

(*c*) Assurance after careful investigation by the reporting agency that

such sanitary defects and health hazards probably do not exist on any water service line used for delivering drinking water to common carrier conveyances. The investigation of such water service lines should include the entire system served by them, beginning with their first point of connection to the water mains of the public water supply system.

With respect to item (*b*), a "sincere effort" may be considered to have been made if it can be shown that:

(1) Satisfactory rules and regulations covering connections or arrangements by which unsafe water may be discharged or drawn into the water supply system are applied to all new construction; remedial measures are taken as promptly as material and labor are available to correct plumbing defects which have come to the attention of the local officials; and a continuing program is instituted to detect hazards on the system.

(2) Evidence is presented indicating that surveys have been made to locate cross-connections between the main supply and auxiliary supplies or any other supply of liquids or chemicals of unknown or questionable safety and active steps have been taken to eliminate or safeguard any such connections found.

If either (1) or (2) above is deficient, provisional certification should be recommended with a definite time limit specified for compliance with Sec. 2.2 in accordance with these criteria.

SECTION 3.1. In evaluating compliance with this item of the standards, it is suggested that the location of the sampling points be selected with care so that a true evaluation of the average condition of the water in the distribution system may be obtained. It should be the aim to attain the minimum number of samples per month set forth in this section. In view of the difficulties with materials and personnel during the war emergency, immediate compliance with the schedule of sampling given in Sec. 3.1 may not be possible. If sincere efforts are being made to build up a sampling program that will, within a reasonable period, attain the objective, such effort should be given proper consideration. Therefore, evaluation of compliance with this requirement should be based on the individual circumstances and extent of the effort made to achieve this schedule.

In determining the number of samples examined monthly, the following examinations may be included, provided all results are assembled and available for inspection and the laboratory methods and technical competence of the personnel are approved by the state health department and/or the certifying authority:

(*a*) Samples examined by the state health department.

(*b*) Samples examined by local health department laboratories.

(*c*) Samples examined by the water works authority (private or municipal).

(*d*) Samples examined by commercial laboratories.

The number of samples to be collected monthly from a distribution system should depend on the population of the municipality or other area served in which the common carrier watering point is located. Samples collected from the service lines of the carrier shall meet the bacteriological requirements of the standards.

Some examples may serve to clarify the above paragraph:

(1) A water district having a total population of 100,000 supplies water to

towns A, B and C. The common carrier involved takes its water from the distribution system of C (population 4,000). The number of samples required monthly from C's distribution system to meet the standards would be two.

(2) City A (population 300,000), in addition to supplying water to its own distribution system, also furnishes water to the distribution system of city B (population 60,000). The common carrier secures its water at city B. Hence, the number of samples taken from the distribution systems of city B in accordance with the standards should be 65 per month.

(3) Using the premise of example (2) again, assume that the common carrier takes water at both city A (population 300,000) *and* city B (population 60,000). Then samples from the distribution system of city A would be at the rate of 170 per month and from the distribution system of city B at the rate of 65 per month. The frequency of obtaining samples from each representative sampling point should be fairly uniform and should be based on monthly samples collected rather than on an annual basis. When few samples are required, the sampling points should be used in rotation.

SECTION 3.1 (*second paragraph, last sentence*). This shall be interpreted to mean the respective state departments of health or their designated representatives in such cases where the Public Health Service has not investigated the supply.

SECTIONS 3.22 and 3.24 (*last sentence in each section*). Such daily samples should *not* be considered as part of the number of samples required by Sec. 3.1. It could easily be the case, particularly in a small system, if such samples were included, that due to some mishap enough such samples could be collected in a period of a few days to meet the minimum sample requirements. Then sampling of the system could cease till the following month, thereby nullifying the purpose the committee had in mind in setting up the minimum sampling schedule as a means of checking at frequent intervals the quality of water distributed in the system.

SECTIONS 3.22 and 3.24. The occurrence of three out of five tubes positive when 10-ml. portions are used, and of five tubes positive when 100-ml. portions are used, requires immediate collection of daily samples from the same sampling point. If the next sample collected was likewise positive in three 10-ml. or five 100-ml. tubes, depending upon the size of portions used, consecutive samples with poor showings would have been obtained. One interpretation of Secs. 3.22 and 3.24 would then be that the supply could not be certified. It is considered that the proper interpretation is that if the second sample also shows contamination, immediate and active efforts should be taken to locate the cause of such contamination and measures should be taken to remedy any unsatisfactory conditions found in the supply. If the record showed a clearing up of bacterial contamination in the supply and the application of the necessary corrective measures to any unsatisfactory conditions found, it would be reasonable to approve the supply if it conformed in other respects with the bacteriological requirements. If, upon obtaining three of five 10-ml. portions positive or five of five 100-ml. portions positive, no steps were taken to collect daily samples and the next regular sample from this

sampling point was likewise positive, then non-compliance with the standards would be indicated and non-certification of the supply could be considered justifiable.

SECTION 4.1. Turbidity and color requirements should be met by all filtered water supplies. Compliance with turbidity and color limits for unfiltered waters and with the requirement of freedom from objectionable taste or odor for all waters should be based on reasonable judgment and discretion, giving due consideration to all the local factors involved.

SECTION 4.2. *Chemical characteristics*—Semi-annual examinations for the substances listed in Sec. 4.21 should not be required where experience and examination indicate that such substances are not present or likely to be present in the water sources involved, provided that a statement to that effect is made by the state health department, supported, where possible, by additional evidence from other state agencies.

Where such substances may be present in the delivered water because of the addition of water treatment or conditioning chemicals, or because of the composition of water distribution piping, semi-annual or more frequent examinations should be made of samples collected from representative points in the distribution system to ascertain the concentration of these substances.

SECTIONS 1.6 and 4.2. Because of the terminology of these two sections, some persons have interpreted Sec. 4.2 as limiting the use of certain materials in piping systems. This was not the intent of the Advisory Committee nor is it the interpretation which the Public Health Service gives to the wording of these sections.

State Health Officers' Circular Letters No. 28 (1938) and No. 78 (1944)

It is believed that interpretation of the Public Health Service Drinking Water Standards in accordance with the preceding policy will clarify to a great extent the provisions of Circular Letter 78.

Attention is directed to the last sentence of the second paragraph on page 2 of Circular Letter 78, with regard to "provisional" certification:

> It is believed that the continuous use of a "provisional" certification serves no useful purpose and therefore, beginning with the calendar year 1944, recommendations for "provisional" certification will be accepted only if a definite time limit is specified for correction of existing major defects. This time limit will not exceed twelve months in the case of water supply sources as well as in watering practices requiring major construction. This time limit will not exceed three months where changes of a minor nature in watering practices are required. *An extension to these time limits will be granted whenever a shortage of critical material or other major reason requires such extension.*

Where there is recognition of the shortcomings of an interstate carrier water supply by the water works authority and a sincere effort is being made to correct these shortcomings, the Public Health Service will, upon recommendation of the reporting agency, consider all of the facts involved before demanding strict adherence to the specified time limit of twelve months.

If, on the other hand, the water works authority shows no inclination to rectify the conditions which would normally call for prohibition of use of the supply, in accordance with reasonable interpretation of the standards, there will be no leniency in the adherence to the time limit specified.

Likewise, in the case of defects in watering equipment or practices for which the interstate carrier is responsible, the twelve-months and three-months "dead-lines" specified for major or minor defects, respectively, will warrant adherence or extension in accordance with the sincerity of effort on the part of the carrier to make the necessary correction, as judged by the reporting agency.

In the case of defective plumbing constituting public health hazards as referred to in the last sentence of paragraph (4) of State Health Officers' Circular Letter No. 28 of April 18, 1938, quoted below, the interpretation enunciated in Part I of this policy statement, for Sec. 2.2 of the standards, will govern.

(4) Supplies meeting the Treasury Department Drinking Water Standards in all particulars shall be recommended for favorable certification. Supplies having potential health hazards either in structure or operation shall be recommended for provisional certification or prohibitive certification, depending upon the seriousness of the health hazard. Supplies having cross-connections with other supplies of unsafe character or of unknown sanitary quality shall in no instance be recommended for favorable certification, unless such cross-connections are protected in a manner approved by the state department of health having jurisdiction and are inspected regularly by an agent of such department. By-passes between raw and treated supplies shall be considered as cross-connections. With the exception of connections between swimming pools and the water supply systems, cross-connections existing between waste piping and water piping systems of buildings shall not be considered as a part of the water supply distribution system in making recommendations as to certification.

(Signed) L. R. THOMPSON
Acting Surgeon General

Editorial Comment

The 1942 Drinking Water Standards were published in this JOURNAL, **35**: 93 (1943). At the January 1944 meeting of the A.W.W.A. Board of Directors, consideration was given to certain details of the standards and resolutions were adopted and officially transmitted to the Surgeon General, U.S.P.H.S. (see JOUR. A.W.W.A., **36**: 213 (1944)).

On Apr. 17, 1944, a conference was held in Washington between representatives of the U.S.P.H.S. and the A.W.W.A. A full account of this conference appeared in this JOURNAL, **36**: 781 (1944).

It might be considered presumptuous to assume that Circular Letter No. 85 (hereinbefore published) results from the expression of opinions officially for the A.W.W.A. It is noted, however, that the letter relates to many of the issues raised by the A.W.W.A. and outlines a policy for interpretation of various sections of the standard which were questioned by the A.W.W.A. representatives. Circular Letter No. 85, therefore, should be reviewed in its relation to the prior discussion and a conclusion reached by the reader on whether the points at issue have been disposed of through the mechanism of this letter.

It may be noted that insofar as the basic concept of what such a standard should be and should contain, major differences of opinion still exist. The statement reads in part: "Many of the difficulties encountered thus far in the application of the 1942 Drinking Water Standards may be attributed to their consideration as engineering specifications rather than as standards. Naturally a standard of measurement or

comparison, a model to be followed, should be developed so that progress and improvement are achieved or stimulated."

The A.W.W.A. representatives did not and still do not agree with this theory. It is their opinion that a standard, whether it be of materials, of performance or of quality, should contain terms and conditions which are attainable by any agency which exercises adequate control of production or operation. A standard should be always strict enough to obtain the objective, which in this case is safe drinking water for interstate carriers.

Standards should be attainable with good practice, not statements of objectives beyond present conditions and reasonable attainment. Standards should be precisely related to the objective and not contain subsidiary requirements which are not within the control of the agency responsible for the product. And in short, the A.W.W.A. advocates, in the words of George C. Whipple (JOUR. A.W.W.A., **12**: 67 (1924)) the following principles applicable alike to building construction, plumbing, control of water supplies and other matters of sanitation:

"1. Government requirements, not too high, intended to prevent injury, and justifiable under the police power, to be established by law.
2. Professional standards of excellence, standard specifications, grading, and the like, higher than government requirements, to be established by agreement, not by law.
3. Government requirements and professional standards to be interlocking.
4. Government requirements to be uniform in the different states as far as practicable, in order to facilitate the establishing of professional standards by agreement.
5. Professional standards to be varied geographically, or in other appropriate ways in order to meet practical conditions."

In summation, water works men generally and the A.W.W.A. officially, will doubtless be appreciative of the consideration given to their problems by the officers of the U.S.P.H.S. as evidenced by the issuance of Circular Letter No. 85. They will also doubtless continue to apprehend that fundamental differences exist between the concepts of the purposes and content of the Drinking Water Standards as they exist, on the one hand within the Public Health Service and on the other hand in the field of water supply engineering and administration.

HARRY E. JORDAN,
Secretary

Abstracts of Water Works Literature

Key: In the reference to the publication in which the abstracted article appears, **34:** 412 (Mar. '42) indicates volume 34, page 412, issue dated March 1942. If the publication is paged by the issue, **34:** 3: 56 (Mar. '42) indicates volume 34, number 3, page 56, issue dated March 1942. Initials following an abstract indicate reproduction, by permission, from periodicals, as follows: *B.H.—Bulletin of Hygiene (British); C.A.—Chemical Abstracts; P.H.E.A.—Public Health Engineering Abstracts; W.P.R.—Water Pollution Research (British); I.M.—Institute of Metals (British).*

CHEMICAL ANALYSIS

The Use of Photoelectric Spectrophotometric Techniques in Chemical Analysis. J. W. STILLMAN. A.S.T.M. Bul. *No.* 125: 17 (Dec. '43). First photoelec. instruments, as suggested by biochemists, attempted to substitute photocell for human eye, but retained rest of visual instrument intact. *Spectrophotometer*, essentially *spectrometer* plus a *photometer*, measures absorption of light of any wave length through a soln. *Colorimeter* measures color of light. Duboscq instrument really a *color comparator*. Most photoelec. instruments *absorptiometers*, using either white light or certain spectral band. If series of spectral ranges covered, instrument is "*abridged spectrophotometer.*" Requirements for satisfactory colorimetric method include: color must be characteristic; reaction must be sensitive; color should be somewhat stable; density of color should vary directly with concn. of solute, i.e., follow Lambert-Beer law; interferences should be eliminable. Wave length attended by max. absorption used in analytical detn. though not necessarily optimum point. Spectrophotometry allows resolution of color systems contg. two or more color components. Transmittancy values at optimum wave length plotted for different concns. of solute comprises calibration curve for detg. unknown concns. Complete photoelec. spectrometer contains light bulb for continuous visible spectrum or hydrogen discharge tube and quartz system for ultraviolet region, with prism or grating to separate various wave lengths. Commercial instruments obtain desired wave bands by means of filters. 10 references.—*A. A. Hirsch.*

The Determination of the Acidity of Natural Waters. L. COIN. Ann. Hyg. Publ. Ind. Sociale (Fr.) **20:** 145 ('42); Chem. Zentr. (Ger.) **I:** 2124 ('43). Detn. of free CO_2 gives low results. Detn. of pH more satisfactory. Best method is to treat H_2O with marble and follow change of pH until H_2O satd. Amt. of material required to give any desired deg. of protection from acidity can then be calcd. —*C.A.*

Micro-determination of Copper and the Application of the Method to Venetian River Water and Fresh-Water Fish. M. PICOTTI & G. BALDASSI. Mikrochemie ver. Mikrochim. Acta 30: 77 ('42). Na salt of diethyldithiocarbamic acid probably more sensitive to traces of Cu than any other reagent proposed, detecting as little as 0.01γ Cu. Trivial name diethyldithione proposed. Brown color produced can be measured in Pulfrich photometer with filter S/45 or S/43. To carry out test, make aq. soln. slightly ammoniacal, add reagent and shake with acetic ester. 2 ml. 0.5% reagent sufficient for 100γ Cu. Ether and isopropyl alc. can also be used as solvent but acetic ester preferred. To prevent interference, some Na_2HPO_4 should be added to ammoniacal soln. before adding reagent; this ppts. interfering ions as phosphate. Some 19 samples of Italian R. water studied and 5.7–47γ Cu per 1. found. 4 kinds of river fish tested and found to contain 3–37γ Cu per 100 g. body wt. The fact that some fish thrive better in certain rivers than in other waters quite likely due to varying Cu content. —*C.A.*

An Accurate Direct Quick Method for the Determination of Cl in Water and Sewage Containing Interfering Substances. O. STURZ. Chem-Ztg. (Ger.) **67:** 57 ('43). Aliquot part of water (100 ml.) in question mixed with 1 ml. of HNO_3 (about 4 *N*) and 20 ml. of ether. ½ ml. of diphenylcarbazone soln. (1% alc. soln.) added and mixture titrated with 0.0282 *N* soln. of $Hg(NO_3)_2$, rotating vigorously until end point reached—red color preceded by brown yellow in ether layer. Important to use correct amt. of indicator as excess gives low results. Effect of excessive amts. of Fe, $MgSO_4$, peroxide, sulfite, sulfide and nitrite studied. 5 tables given showing results obtained upon addn. of known amts. of interfering substances.—*C.A.*

The $CaO-H_2CO_3$ Equilibrium in Pure Solutions and in Natural Waters. JOHANNES KEGEL. Gesundh.-Ing. (Ger.) **65:** 48 ('43); Chem. Zentr. (Ger.) **II:** 58 ('43); C.A. **37:** 5523. True aggressive CO_2 content differs from that calcd. from combined and free CO_2 or pH value. Explained on basis of lime-carbonic acid equil. curve and method of obtaining correct values by considering influence of Mg salts described.—*C.A.*

Colorimetric Determination of Ammonia With Nessler Reagent. ERNST GEIGER. Helv. Chim. Acta (Swiss) **25:** 1453 ('42). With due consideration to views held by various investigators since Nessler first studied reaction in 1856, conclusions drawn from many expts. here described, undertaken for purpose of detg. best conditions for making test are: (1) NH_3 in basic soln. reacts with $K_2[HgI_4]$ to form OHg_2NH_2I as Nessler assumed. Reaction reversible and addn. of KOH helps to form colored compd. and addn. of KI reverses reaction. (2) No reaction takes place at pH less than 12. (3) In solns. which are 2–12 *N* in KOH and at 18–70° "oxydimercuriammonium iodide" formed. (4) In solns. 0.1–1.0 *N* in KOH some formation, as well, of double iodide $(OHg_2NH_2I)_2 \cdot HgI_2$. (5) In 0.01–0.1 *N* KOH reaction incomplete. (6) In carrying out colorimetric detns., alky. should be 0.105–0.135 *N* in KOH or NaOH. (7) Suitable K iodomercurate soln. used as reagent contains excess of HgI_2 which reacts with KI formed during color formation to form more K_2HgI_4. To prep. reagent, dissolve 23.88 g. pure KI in 100-ml. volumetric flask in as little water as possible. Add 36.40 g. HgI_2 and, when dissolved, dil. to mark and mix. One ml. of reagent should react with 6.8 mg. of NH_3. Formation of $NH_2 \cdot Hg_2I_3$, as assumed by Nichols and Willits (C.A. **28:** 3023) could not be verified. Such a ppt. should contain 46.3% Hg and 51.4% I. Ppts. which contained least Hg and most I contained 68.3% Hg, 27.7% I and 2.26% N.—*C.A.*

Colorimetric Determination of Fluoride in Natural Waters With Thorium and Alizarin. N. A. TALVITIE. Ind. Eng. Chem.—Anal. Ed. **15:** 620 (Oct. '43). Thorium alizarin lake method involving hydrolytic, adsorption and complex-ion equilibria, adapted to anal. of natural waters similar to zirconium lake procedure, thereby overcoming slowness of reaction, tendency for lake to ppt. and instability of reagents. *Procedure:* To 100-ml. water sample add 5 ml. of alizarin indicator (0.0855 gm. alizarin monosodium sulfonate per liter); titrate with 0.3 *N* nitric acid to yellow. Dil. to 110 ml. in Nessler tube, add 5 ml. 0.001 *M* thorium nitrate, also contg. 1 *M* sodium sulfate, formic acid and sodium formate. Compare with stds. in 30 min. Mechanism of reaction, interferences and effect of temp. discussed. By applying small corrections, results to 0.1 ppm. F obtainable when sample does not contain more than 1000 ppm. of commonly occuring ions.—*A. A. Hirsch.*

Improvement in the Determination of Magnesia With Potassium Palmitate in Technical Raw Water Analysis. OTTO MICHAELIS. Wärme (Ger.) **64:** 368 ('41); Chem. Zentr. (Ger.) **I:** 1792 ('42). To avoid insensitive color change from white to red in carrying out palmitate titration in presence of oxalate, a measured excess of 0.1 *N* palmitate soln. added to appearance of deep-red color in sample prepd. in usual way and treated with 20 ml. of satd. $Na_2C_2O_4$ soln. Sample back-titrated with 0.1 *N* HCl, 1 ml. of 0.1 *N* HCl being equiv. to 2.0 ml. of 0.1 *N* palmitate soln. in presence of oxalate. Mg values obtained deviate up to 0.6% from gravimetric values.—*C.A.*

Determination of CO_2 in Water. D. S. MCKINNEY & A. M. AMOROSI. Ind. Eng. Chem.—Anal. Ed. **16:** 315 ('44). With exception of evolution method, titration methods, especially when used to det. small amts. of CO_2, defective in one or more of following: (1) Indicators used do not change color at optimum pH values. (2) Titration carried

out by observing color change, and not to precise pH values. (3) Corrections for presence of interfering substances uncertain. Method described overcomes these defects by titrating sample between two properly selected pH values, acidifying and boiling off CO_2, cooling sample, and retitrating between same two pH values. Difference between two titrations gives CO_2 in sample. Precision of ± 1 ppm. can be attained. App. readily available used and no knowledge of nature or concn. of interfering substances, except sulfides, required. From study of inflection points of calcd. titration curves, pH values of 8.5 and 5 selected for titrations; pH values of 9 and 5 slightly better in water contg. phosphates. Indicator trials led to selection of methyl red mixed with o-cresolphthalein. Phenolphthalein can replace latter. Complete details included for reagents required, anal. procedure, correction for interfering substances in NaOH titrating soln., as well as for acid gases other than CO_2, and calcn. of CO_2. Because of rapid reduction of methyl red on boiling, samples contg. large quants. of either H_2S or SO_2 cannot be successfully titrated by procedure described.—*C.A.*

The Objective Determination of Odor in Water Investigations. G. NACHTIGALL & E. GRILL. Arch. Hyg. Bakt. (Ger.) **129:** 196 ('43). Volatile org. constituents at least partly responsible for odor of natural waters and odor roughly proportional to their presence. For objective detn. of odor, therefore, 25 ml. distd. from 1 l. of water and distillate oxidized with $KMnO_4$. O-tolidine used for detn. of excess $KMnO_4$. Results expressed as "odor number"; i.e., number of gammas of $KMnO_4$ used for 1 l. of original water. Free chlorine interferes and original water must be treated with thiosulfate before test. Short summary of significance of odor test in evalg. water given. Test results on a no. of water samples analyzed by $KMnO_4$ procedure given and values compared with other characteristics of water such as odor or source.—*C.A.*

Photocolorimetric Determination of Humous Substances in Water. S. A. GUSINSKAYA. Nauch. Zapiski Dnepropetrovsk. Gosudarst. Univ. (U.S.S.R.) **15:** 5 ('40); Khim. Referat. Zhur. (U.S.S.R.) **4:** 9: 92 ('41). Detns. made by means of Davydov photocolorimeter with Se photo-element and light-blue light filter. Soln. made from Merck prepn. of humic acid. Sample dissolved in 0.1 *N* NaOH and dild. with water to 100 ml. Color obeys Lambert-Beer law within range of 1–35 mg./l. humic acid. Presence of other components of natural water such as Ca^{++}, Mg^{++}, Na^{+}, Cl^{-}, HCO_3^{-} and SO_4^{--} in concns. below 1.5 *N* had no effect on intensity of color. Each deg. of color corresponded to 0.0625 mg. humic acid per l. of soln. In water with total mineralization less than 1–2 g./l. humous substances can be detd. by calibration curve constructed for solns. of humic acids prepd. by dilg. a std. soln. of 1 g. of humic acid in 0.02 *N* NaOH.—*C.A.*

Photocolorimetric Determination of NH_3 in Water. S. A. GUSINSKAYA & A. K. CHERNOVA. Nauch. Zapiski Dnepropetrovsk. Gosudarst. Univ. (U.S.S.R.) **15:** 15 ('40); Khim. Referat. Zhur. (U.S.S.R.) **4:** 9: 86 ('41). In reaction of NH^{+} with Nessler's reagent, color reaches its max. intensity 9–10 min. after addn. of reagent and remains const. for 60 min. At 20–5° change in intensity of color with concn. of NH_3 obeys Lambert-Beer law. Effects of $MgCl_2$, $CaCl_2$ and $FeCO_3$ on reaction studied. Large amts. of humic substances (color greater than 90°) interfere with detn.; prelim. coagulation of colored substances necessary in such cases.—*C.A.*

The Chemical Analyses of the Waters of Oklahoma. OTTO M. SMITH. *Contributors:* ROBERT H. DOTT & E. C. WARKENTIN. Okla. A. & M. College Eng. Expt. Sta. Pub. No. 52 (Oct. '42). [474 pp., $2.50 at College Book Store, Stillwater, Okla.] State of Okla. unique in that it contains water which varies in amt. of mineral content from only few ppm. solids to satd. brines contg. over 28% solids. Every type of water found in state included in 2935 anals. given in logical and orderly arrangement. Material made more readily usable by 13 tables, 21 dwgs. and 15 photos supplemented by carefully prepared index. One aim of publication to show, for every city, all available, complete mineral anals. of municipal supply, and to give such data for sufficiently large number of local supplies to indicate probable type of water in surrounding territory. 5 chapters (90 pp.) make up Part I, "Uses of Water in Oklahoma," "Geology of Ground Water Supplies," "Hardness," "Fluorides," and "Methods of Analysis." In Part II, anals. arranged in 3 chapters: "City Supplies, Wells, Lakes,

Ponds and Small Streams"; "Rivers and Large Streams"; "Mineral Waters and Brines." Arrangement of anals. of first group in Part II alphabetical by counties, giving hypothetical combinations, in ppm. Same order repeated for same waters in ionic anals., expressed both as ppm. and as mg. equivalents per liter (E/l.). Similarly hypothetical combinations and ionic anals. given for rivers, divided into basins of Arkansas and of Red, with subdiv. into main rivers and tributaries in each basin. Discussion of medicinal value of certain waters followed by brief descriptions, with anals. of mineral waters and brines, stated in ppm. and in gpg. Anals. obtained from 3 sources: publications of governmental agencies and private institutions, unpublished files of business concerns, tests made for this publication.—*Harrison Hale.*

LABORATORY CONTROL—EQUIPMENT AND APPARATUS

Collecting a Sample of Water for Bacteriological Analysis. The Clarifier. **8:** 5, **6:** 3 (May–June '43). If possible, collect all samples from tap or faucet. Try to get one sample as water leaves well, others from distr. system. Flame tap or faucet with blow torch to kill bacteria clinging thereto. Do not pass flame lightly but hold thereon until evident metal hot. Direct flame against inside edge. Turn on and let water run until confident flow represents water fresh from

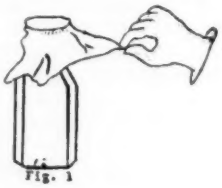


Fig. 1

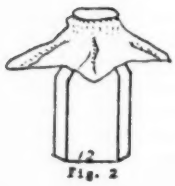


Fig. 2

main. Then remove bottle from container and pull out 4 corners of covering as in Fig. 1, forming umbrella (Fig. 2). Do not remove covering from stopper. Holding bottle in one hand, with other remove stopper and covering (Fig. 3). Do not lay these down but hold in downward position to shield stopper from falling dust particles. Hold bottle under faucet and fill approx. to line in Fig. 3. Allow only small but steady stream to flow from faucet when filling. Avoid splashing bottle lip more than necessary. Immediately remove bottle from under faucet and replace stopper. Press covering around neck of bottle and return it to container. During

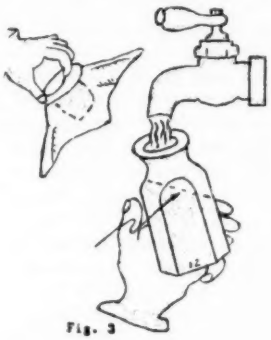


Fig. 3

operation do not touch stopper or lip with covering as some dust-carried contamn. on latter might be washed into bottle.—*Ralph E. Noble.*

Method for Determining Total Solids in Mineral Waters, Brines and Other Salt Solutions. I. V. Tananev & M. I. Levina. Doklady Akad. Nauk S.S.S.R. (U.S.S.R.) **41:** 173 ('43); Compt. rend. acad. sci. U.R.S.S. (In English) **41:** 165 ('43). Following method applicable to brines, etc., contg. $CaCl_2$, $MgCl_2$ and similar salts undergoing partial decompn. on heating: Weigh 1–1.5 g. NaF (previously heated to 180°) into a suitable vessel, add sample of brine, reweigh, dry first at 100–110° and then to const. wt. at 180°. Tabulated data show results obtained with new method agree closely with those obtained with similar though less convenient method with Na_2CO_3. —*C.A.*

Importance of Properly Collecting a Water Sample. ANON. The Clarifier. **8:** 5, **6:** 2 (May–June '43). Properly flaming tap before collecting sample important. Many samples show contamn. even though water considered free therefrom. In most cases, bacteria present due to improper sample collection. Simplified tap flaming method before sample collection described. Instead of inconvenient blow-torch, only bottle of alc., cotton and stick or wire required. Wrap end of stick or wire with cotton and dip in alc. Light swab and flame tap thoroughly before letting water flow. Then allow to flow 5 min. or long enough to insure fresh water coming from main before taking sample. Proper selection of sampling points important. Should be well scattered over distr. system for representative sampling, taking one from source effluent. Sampling point should be easily accessible; tap or faucet without leaky valve stem.—*Ralph E. Noble.*

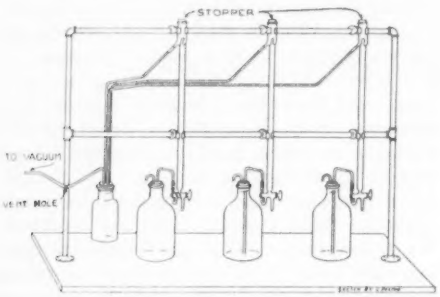
Bacteriological Examination of Chlorinated Water: The Use of Thiosulfate-Treated Bottles for Collecting Samples. RUDOLPH E. THOMPSON. Can. Engr.—Wtr. & Sew. **82:** 2: 27 (Feb. '44). Thiosulfate-treated bottles employed in Toronto since May '39, 1 ml. of soln. of 7.5 g. $Na_2S_2O_3 \cdot 5H_2O$ per 1. being introduced into each 145-ml. bottle prior to hot-air sterilization. Water contg. 0.75 ppm. Cl immediately dechlorinated when collected in such bottles that have been subjected to as many as nine 3-hr. sterilization periods at 230–250°C. Data presented to show that amt. of thiosulfate used sufficient to remove about 21 ppm. Cl if no decomposition occurs during sterilization. As superchlorination employed in Toronto when raw water is pold. and long contact periods available for disinfection, water entering distr. system practically sterile at all times. No significant difference in results noted, therefore, since employing treated bottles. Nevertheless, believed that bact. examn. provides no definite assurance that water of qual. indicated by test unless any possibility of continued disinfection after collection of sample definitely elimd. Series of duplicate samples from supply treated by $Cl-NH_3$ process indicated that considerable disinfection occurred during interval between sampling and examn. when samples not dechlorinated immediately. During past 13 yr., bact. count on treated Toronto water has avgd. 0.87 per ml. Observations on control plates prepd. over period of years indicate that probably half this avg. count has been due not to bacteria in water but to bacteria introduced during prepn. of plates. 10 references.—*R. E. Thompson.*

An Easier Method for Determining Suspended Solids. ALICE L. MATHIS. W.W. & Sew. **90:** 10: 386 (Oct. '43). Use of Gooch crucible for suspended solids detn. inaccurate because loss of even shred of asbestos causes appreciable error in final results; filter papers also inaccurate since wt. varies with atm., temp. and humidity. Suggested procedure involves 4-place centrifuge. Mixed sample placed in carefully dried and weighed 50-ml. tubes. Centrifuged at top speed for 20 min. After decanting, residue oven-dried for 1 hr., cooled in desiccator for 2 hr. and weighed. Wt. of residue in mg. times 20 equals ppm. suspended solids. To reduce error resulting from inclusion of dissolved solids in supernatant, liquid portion should be poured off smoothly and quickly. Tubes easier to prepare and use than crucible; no danger of losing part of tube as in crucible method; tubes easier to weigh accurately.—*F. J. Maier.*

The Determination of Soluble Phosphate and Silica in Water by Means of the Spekker Photoelectric Absorptiometer. T. S. HARRISON & H. STORR. J. Soc. Chem. Ind. **63:** 5: 154 ('44). Procedure described for detn. of PO_4 (**I**) and SiO_2 (**II**) each in absence of other. Method based on controlled reduction of phosphomolybdate and silicomolybdate with Na_2SO_3 by quinol. Mo-blue coloration measured on Spekker absorptiometer with Ilford red filters No. 608. Drum reading converted into **I** and **II** by means of graph based on known solns. under same std. conditions. Detn. of either radical made possible by maintg. suitable conditions of acidity. Tests included to study effect of diverse ions as SO_4, Ca, Mg, Fe and Al. Detn. requires about 30 min. on sample of approx. 40 ml. and results compare favorably with gravimetric anals. Spekker app. suggested to follow veloc. of certain reactions.—*C.A.*

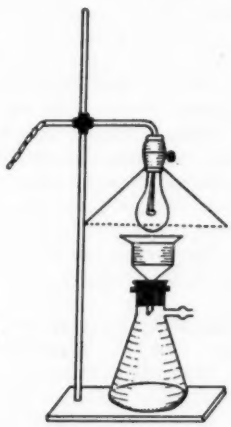
An Automatic Burette Set-up. BENJAMIN S. FLUG & RAYMOND E. KARCZYNSKI. Chem. Analyst **33:** 2: 40 (May '44). Automatic set-up found to be very satisfactory and great

time-saver in control labs. Has further advantage over some gravity feed systems in that reagent does not have to be pumped back to stock bottle. Filling of burette accomplished by means of vacuum from pump or aspirator, and, although all burettes are hooked up to one vacuum line by means of a trap, each can be worked independently. After vacuum line opened, burette is filled



by holding a finger over vent hole (see fig.) and turning stopcock into position to connect with stock bottle. When burette is filled, turn cock and remove finger from vent. Any overflow will run down to trap. Trap should be arranged in such a way as to allow emptying when necessary.—*Ed.*

Radiant Heat for Filtrations. Louis H. Goodson. Chemist Analyst **33:** 2: 45 (May '44). Simple method of keeping funnel and its contents hot during filtration illustrated in accompanying fig. Source of heat is elec. light bulb with reflector. Ordinary reflector, originally designed for use in photographic lighting, proved satisfactory. Size and type of bulb can be varied, but clear 150-w. lamp worked nicely for heating 6″ funnels as high as 80°C. For suction filtrations best results obtained by wrapping funnel with cloth so that filter plate and lower portions of funnel do not become cold. Amt. of heat applied conveniently regulated by raising and lower-



ing light bulb. Watch glass placed over funnel serves to prevent excessive solvent losses. Some advantages are: (1) accurate regulation of temp. is easy; (2) fire hazard created by lamp bulb not great; (3) costly jacketed funnels not required as this set-up easily adapted to nearly all sizes and types of funnels; (4) necessary parts usually available at low cost.—*Ed.*

CORROSION AND CORROSION CONTROL

Quantitative Investigations on the Ability of Naturally Very Soft Waters to Form a Calcium-Rust-Protective Layer and the Degree of Artificial Hardening Required. Kegel. Chem. Tech. (Ger.) **15:** 198 ('42). Deals with calcium carbonate–carbon dioxide equilibrium in water with reference to formation of protective layer by soft waters, and detn. of this equilibrium by means of relation between phenolphthalein and methyl orange alks. (p and m values). Water to be examd. treated with lime water to adjust p and m values so that $2p = m$; at this value no bicarbonates present. Value for $2p = m$ detd. and water then left in contact with calcium carbonate for 1–2 days and shaken frequently. At end of this period value for $2p = m$ detd. again. If value has fallen, calcium carbonate pptd. and water therefore able to form protective layer. If it has remained same, water will not dissolve calcium but it will not form protective layer and will, therefore, corrode iron. If value of $2p = m$ has increased, water aggressive to both calcium and iron. By making another test using chems. which can be used on plant scale (sodium hydroxide, sodium carbonate, sodium bicarbonate, or calcium sulfate) for adjusting p and m values to $2p = m$, possible to calc. deg. of treatment required by soft water to render it able to

form protective layer. If $2p < m$ some bicarbonates as well as monocarbonates present. Bicarbonates dissociate to form hydrogen and carbonate ions; hydrogen ions will make water corrosive and protective layer will not be formed. If $2p > m$ hydroxides present and calcium carbonate tends to separate as sludge instead of forming protective layer. Corrosion therefore not always prevented by increasing pH value, and formation of protective layer occurs only within limited range of pH values. When concn. of calcium and carbonate or bicarbonate ions in water low, p value must be increased to a greater extent than with harder waters to reach value of $2p = m$.—*W.P.R.*

Causes of the Formation of Boiler Scale in Low-Pressure Steam-Heating Plants and Hot-Water Plants and Its Prevention. A. STAMM. Gesundh-Ing. (Ger.) **64:** 535 ('41); W.P.R. **14:** 364 ('41). In detg. causes of formation of boiler scale important to know wt. of scale formed and amt. of raw water needed to produce this amt. of scale. At low-pressure steam heating plant, 375 kg. of scale had formed over area of 150 sq.mi. during period of 3 yr. Raw water used had hardness of 23° (Ger.) and 810,000 l. would be required to produce 375 kg. of scale. Amt. of scale produced would be decreased if amt. of make-up water used could be reduced. In many plants vessels receiving condensate too small and soon overflowed so that considerable quants. wasted; large quants. of steam allowed to escape; water which had condensed in app. overnight wasted; and pipes not regularly examd. and water lost through leaks. Vol. of all make-up water should be measured. Conditions can be improved by addn. of materials for prevention of scale, but good results obtained only by regulating addn. of fresh water. Two main methods for prevention of scale formation. In first method materials added which dissolve hardness-forming materials. Amt. added must be carefully regulated. These materials will dissolve carbonates but will not remove scales consisting of other salts. In second method for preventing scale formation materials which bring about chem. decompn. of hardness-forming materials are added. By careful operation formation of scale can be entirely prevented by this method and old scales can be removed, though noncarbonate scales removed very slowly.—*C.A.*

Corrosion Experiments on Welded and Annealed Specimens. L. HUNSICKER. Autogene Metallbearbeit. (Ger.) **34:** 17: 273 ('41). To investigate mechanism of corrosion of welded and annealed steel, copper and aluminum specimens, expts. carried out to det. elec. surface potentials and time-corrosion curve by means of stationary and alternate-immersion tests for periods up to 250 hr. Effect of corrosion on strength and elongation also investigated. Expts. revealed following: (1) Surface potential of scale-covered material detd. by potential of scale and potential of underlying metal. The greater and stronger the adhesion between scale and metal, the nearer does the resulting surface potential approach that of the scale, and vice versa. Annealing improves surface potential as result of formation of more homogeneous layer of scale. (2) Heat-affected regions of weld show no effects of annealing temp. on corrosion in stationary immersion tests. (3) In alternate-immersion tests on copper, specific corrosion decreased at first and maintd. almost const. value with increasing time. Specific corrosion of steel specimens decreased at first, and after certain time increased rapidly. Corrosion values of cast iron increased rapidly at first, then decreased just as rapidly, to remain const. after certain time. (4) Strength and elongation of specimens decrease in same proportion with increase in time of corrosion. (5) Annealing, by resulting in a finer grain structure, improves corrosion resistance.—*C.A.*

Prevention of Water-Side Deposits in Recirculating Cooling Systems. W. J. THOMPSON & J. W. RYZNAR. Combustion **14:** 5: 41 ('42). Factors affecting formation of insulating deposits and corrosion on water side in recirculating cooling water systems discussed. Studies made on effect of various treatments for scale and corrosion prevention and for control of biol. growth, with emphasis on elimn. of Ca and Mg deposits. Correct evaluation of all factors makes it possible to predict behavior of any make-up water used under any specific operating conditions. Results of chem. anals. of typical recirculating cooling system deposits and of various waters tabulated. In general two methods followed in corrosion prevention in these systems: deaeration of water to remove O and application of chemicals to produce impervious stain or film on surface of metal in contact with water. In lab. expts. protection by stain or film in-

creased greatly when pH of circulating water within correct limits for $CaCO_3$ supersatn. and blended org. phosphates used for scale elimn. Elimn. of growth of sulfate-reducing bacteria by chlorophenate derivatives is of aid in solving economically many corrosion problems of this type. Silt or other suspended material in circulating water may be held by biol. growths and indirectly cause adhering deposits on heat-exchange surfaces. Slime and algae absorb treatment which has been added for scale prevention and systems contg. these growths require heavier stabilizing treatment dosages for best results in scale prevention.—*C.A.*

Corrosion of Metals by Constituents of Molded Synthetic Resin Plastics. W. WIEDERHOLD & GROEBE. Chem. Tech. (Ger.) **15**: 226 ('42); Brit. Chem. Abs. (Br.) B1: 342 ('43). Copper, brass, iron, zinc, aluminum and aluminum alloys partly immersed in 0.01% and 0.1% aqueous solns. of phenol, cresol, formaldehyde, aqueous ammonia, acetic acid, ammonium formate, ammonium oxalate at 40° C. for 105 days. Phenol, cresol and formaldehyde had little more corrosive action that had distd. water, but acetic acid and ammonium salts slightly more corrosive. Iron with oiled or phosphate-treated surface and copper-free aluminum alloys practically unaffected. Metals allowed to remain for 90 days in damp atmosphere at 40° C. in contact with powd. molded plastics, to which ammonium acetate and ammonium oxalate added before molding. Powds. had less effect than dil. solns. and concluded that corrosion of metals by plastics negligible.—*I.M.*

On the Theory of Passivity and Corrosion of Metals. P. D. DANKOV. Bul. Acad. Sci. (U.S.S.R.) **5**: 1249 ('38). Modern theories of passivity and corrosion examd. On basis of data regarding structure of oxide films on metals, in particular iron, necessity of modifying film theory of passivity and corrosion expressed insofar as mechanism of film formation, structure of films and their changes during corrosion concerned.—*I.M.*

Increasing the Chemical Stability of Copper by Passivation in Solutions of Chromates. G. V. AKIMOV & A. I. GOLUBEV. Zhur. Priklad Khim. (U.S.S.R.) **12**: 1620 ('39). Best passivating solns. are: (1) $0.5N$ $K_2Cr_2O_7$ + $0.125N$ CrO_3, exposure 1 hr.; and (2) N $K_2Cr_2O_7$ + $0.01N$ CrO_3, exposure 1 hr. Corrosion of copper after such passivation decreases sharply in air contg. sulfur dioxide, and in solns. of 3% NaCl + $0.01N$ NaOH, 3% NaCl + $0.01N$ HCl and $0.1N$ H_2SO_4. Chem. stability of brass also improves after above treatment, particularly after treatment with N $K_2Cr_2O_7$ + $0.01N$ CrO_3. Stability of aluminium bronze increases after treatment with passivating soln. of $0.5N$ $K_2Cr_2O_7$ + $0.125N$ CrO_3.—*I.M.*

Tests on the Corrosion of Buried Ferrous Metals. J. C. HUDSON & H. A. HOLDEN. Wtr. & Wtr. Eng. (Br.) **46**: 201, 253 (May, June '43). Little systematic work in this field undertaken in Great Britain. However, shortly before outbreak of war extensive program of tests on ferrous and non-ferrous metals and alloys drawn up by Com. of Inst. of Civ. Engrs. Tests on buried iron and steel undertaken with collaboration of Mid-Wessex Water Co. Main object of prelim. work was to ascertain how far conditions of exposure affect exptl. results and thus avoid gross errors with more extensive program. 95 specimens exposed in 6 trenches. 86 iron or steel and 9 zinc. All specimens weighed and strength, breadth and thickness recorded. Iron and steel specimens thoroughly cleaned, scratch-brushed, sponged with hot water and immersed in pickling bath. Zinc specimens scrubbed, dried and polished with soft cloth. All tests made on duplicate specimens. Avg. loss in wt. of specimens equiv. to annual corrosion rate of 1.5 mils (over whole surface). This may be compared with values of 4.3 mils per yr. observed over 5-yr. exposure to indus. atmosphere at Sheffield, and to 4.8 mils per yr. for steel immersed in sea water at Gosport for 14 mo. Deepest pits observed on any one specimen of each material after 3 yr.: vertically-cast iron, 44; sand-cast iron, 78; and ingot iron, 58. Surprising that protection of metal by rolling scale not achieved at expense of increase in depth of pitting. On contrary, advantage, if any, in this respect lies with as-rolled surfaces. Concluded that differences in composition of iron and steel within range of materials tested of minor importance in detg. resistance of ferrous materials to general corrosion when buried in ground. In particular, in contradistinction to atmospheric corrosion, addn. of small amts. of copper to iron and steel has no effect in retarding corrosion under these conditions. Noted after de-rusting c-i. specimens that

vertically-cast specimens had graphitic appearance and that on drawing finger across surface it became covered with graphite. No graphitization apparent on any of sand-cast iron specimens. Effect of depth of burial investigated by burying specimens at 4 depths: 9, 17, 25 and 33″. Two sets exposed, one with surfaces horizontal and other with surfaces vertical. Results indicate that down to depth of 17″ little difference in corrosion rate, but below this, depth rate increases with increasing depth. Avg. pitting greater for vertical than for horizontal specimens. To test effect of proximity of dissimilar materials, specimens of ingot iron sandwiched between specimens of zinc buried at depth of 31″. Loss in wt. of ingot iron reduced by proximity of zinc. Losses in wt. of specimens bear no relationship to distance between them. Pitting of ingot iron appreciably reduced by zinc. Depths of deepest pits appreciably greater for zinc than for ingot iron. Samples of soil taken for examn. from all 6 exptl. trenches. No correlation found between corrosion and any soil characteristics examd. Method in which change in elec. resistance of metallic specimens used to det. corrosion developed by one of authors in '29. Seemed possible that method would be of value in case of buried metals. It can be concluded, from results obtained, possible to follow change in elec. resistance of specimens buried in soil and this change reasonably good indication of extent to which they have corroded.—*H. E. Babbitt.*

The Problem of Copper and Galvanized Iron in the Same Water System. L. KENTWORTHY. Engineering (Br.) **156:** 85, 125, 164, 205 (July 30, Aug. 13, Aug. 27, Sept. 10, '43). Examn. of certain bi-metal installations gave strong indications that copper circulating pipes did accelerate corrosion of galvanized hot-water containers to which they were connected. Other instances discovered where no harm had resulted from such combination. Trouble might be caused due to slight but definite solvent action of certain waters on copper, since copper taken into soln. might be deposited on galvanized coating. Direct electrolytic action might occur. Two cases of premature failure of galvanized tanks connected to copper pipes provided exceptionally valuable information. First case concerned houses on 2 estates erected by same builder, operating on same water and equipped with identical hot-water systems, except that galvanized tanks on one estate fitted with copper pipes and on other with galvanized pipes. Of 1000 installations on estate fitted with copper pipe, 50% failed in 4 yr., whereas on other, which consisted of 50 houses, no failures had occurred in 6 yr. Second case concerned 2 neighboring estates both equipped with identical copper pipe galvanized tank installation but operating on different water supplies. On one estate every installation failed in 4 yr. On other no failure experienced in 10 yr. Samples of hot circulating water taken from estate where trouble occurred possessed avg. Cu content of 0.32 ppm., while samples from other estate contained only 0.03 ppm. Free CO_2 present to extent of 4.1 ppm. in water where failures occurred, whereas other water contained only 1.1 ppm. Copper installations found to have influenced life of galvanized cold-storage cisterns. Usually result of badly designed installations in which cisterns placed so close to hot containers that back circulation took place. No evidence that increased corrosion of galvanized iron caused by direct electrolytic stimulation. Corrosion of galvanized components of water installations almost entirely due to copper dissolved by water and deposited on galvanized coatings. Specimens of zinc and galvanized iron immersed in solns. of 220 ppm. of CaCl and 80 ppm. $NaHCO_3$ and in softened and untreated tap water contg. small amts. of copper, and, for comparison, in similar copper-free solns. Visual effect on copper marked, severity of pitting and darkening of color increasing on both zinc and galvanized iron specimens with amt. of copper added to water. Ratio of wt. lost by zinc to copper abstracted from soln. in exact agreement with ratio of equivalent wts. of 2 metals. Tests conducted in which service conditions reproduced on lab. scale by means of small-scale circulating systems. Galvanized specimens placed in top reservoir, representing hot tank, into top of which water continuously fed from boiler. Test length of copper pipe inserted in flow pipe which was otherwise made of glass. Temp. of water in hot tank maintd. at 75° to 80° C. Results showed that addn. of copper up to 0.3 ppm. caused increased attack of galvanized iron almost directly proportional to amt. of copper present. Next step, to det. whether hot water circulating through copper pipes could pick up sufficient copper to increase its attack on galvanized iron. 9 circulators fitted up to operate with 3 different waters.

In all 3 waters total wt. of metal attacked greater in circulators fitted with copper pipes. Presence of copper shortened, by at least half, length of life of coating. Obvious solution is to avoid constr. of hot-water circulating installations composed partly of galvanized iron and partly of copper. 2 most effective methods of reducing cupro-solvency of waters consist in removing CO_2 and adding scale-forming constituents. Addn. of small amts. of zinc salts also of value. Dissoln. of copper may be reduced by contact with more electro-neg. metal, such as zinc. Protection afforded to copper will decrease as distance from junction of 2 metals increases and rate of soln. of anodic metal may be impaired by formation of film of insol. corrosion products. 7 lab. circulators fitted up. Metallic zinc provided either by small zinc pipe attached to copper pipe or by small zinc sheet attached to galvanized specimen. From practical point of view, zinc pipe method far more hopeful; zinc sheet method would necessitate impracticably large area of zinc to protect galvanized water tank. Efficacy of metallic zinc in system as remedial measure greatly improved if zinc placed in direct elec. contact with copper. 3 circulators fitted up for tests on effect of zinc-salt addns. with std. lengths of copper pipe, one being operated on water A, and other 2 on same water with zinc sulfate addns. of 2.5 and 10 ppm., resp. No galvanized specimens placed in hot tank, efficacy of treatment being judged solely on copper content of water. Approx. 50% reduction in copper dissoln. achieved by addn. of 2.5 ppm. of zinc sulfate. 8 circulators set up, 7 being fitted with metal or alloy flow pipes, eighth being of glass. Water A used in all circulators. Outstanding result of these tests is excellent performance shown by pre-treated aluminum-brass. Tests carried out on various forms of filters to extract copper from soln.; first using magnesia and chalk. Proved effective in retaining copper but found to be too impervious. Of possible remedial measures tested, zinc turnings as filter medium appeared most easily applied in practice.—*H. E. Babbitt.*

An Adjusted Brine Checks Corrosion. GEO. A. POPE. Power **88:** 369 (June '44). Sodium chromate, to retard corrosion, effective with correct pH. Chart described whereby, given amt. of NaOH required to bring a 100-ml. sample to pH 8.0, possible to det. lb. per 1000 gal. of NaOH and $Na_2Cr_2O_7$ necessary to convert brine to same pH.—*C.A.*

Corrosion of Condenser Tubes by NH_3. ERNEST B. HARRISON. Power Plant Eng. **48:** 6: 84 ('44). Although feed water contained up to 0.5 ppm. NH_3 for many years, no trouble with condenser tube corrosion encountered until '39, and then in only one condenser, differing in design from other 3. Tubes were arsenical Cu and tube sheets Muntz metal. Trouble encountered mainly in winter months, attributed to low water temp., causing almost complete condensation in first pass, leading to formation of more or less concd. soln. of NH_3 or $(NH_4)_2CO_3$ in second pass. Believed that some corrosion fatigue increased damage. As means of minimizing corrosion, temp. of injection water increased to min. of 45° F., and 2 auxiliary air offtake connections added. Comparative tests of stainless steel, Admiralty and arsenical Cu tubes in condenser indicated that arsenical Cu tubes failed first—all tubes failing will be replaced with special Admiralty tube. Corrosion of stainless tubes about one fifth as much as Admiralty and one eighth that of arsenical Cu.—*C.A.*

Water Engineers' Problems. JAMES N. STIRLING. Surveyor (Br.) **103:** 124 (Mar. 17, '44). Suggested that where chlorination practiced tuberculation of pipes may be arrested. In '37 about 400 yd. of 3″ c-i. pipe lined in situ with cement. Reduced diam. to about 2½ to 2⅜″. Supply so much improved no complaints since. Algae troubled intermittently and to slight extent for short periods. Moot point whether due to biol. cause or change of draw-off level. Suggested that consumption should vary approx. as square root of supply pressure. On test of limited section found that consumption fell considerably more than in proportion of square root of head. Metering may be both logical and practical solution to water waste. First lengths of 4″ and 5″ steel mains laid in '26–'27. Since then several miles of tubes up to 6″ in diam. laid, coated inside and outside with appreciable thickness of bitumen. They are answer to tuberculation problem—bitumen does not taste water, pipes seem to retain smooth surface, no burst pipes in spite of 2 severe winters and service connections successfully tapped in ordinary way.—*H. E. Babbitt.*

The Effect of Water on Aluminum Plant. ANON. Light Metals **6:** 68: 420 ('43); Review by H. LICHTENBERG. Korrosion u. Metallschutz (Ger.) **16:** 7: 251 ('40). Expts.

showed that water contg. oxygen forms protective film on aluminum, limiting attack to initial stages. This attack intensified at water/air surface. No attack with carbon dioxide or hydrogen sulfide. Chlorides intensify attack and tend to accentuate pitting. Sulfates give general attack. Presence of heavy metal salts particularly harmful. Hard waters tend to form protective coatings and less harmful than salts. Concn. of salts, e.g., by boiling, accentuates attack. Effect of artificially softening water depends on material used: mineral base-exchangers dangerous; org. base-exchangers and hydrogen zeolite exchangers, where acids afterwards removed, are not. Danger from steam lies in its erosive rather than corrosive action. Inhibitors such as chromates, silicates and naphtenic acids, and sacrificial measures, such as zinc in contact with aluminum, often very beneficial.—*I.M.*

Galvanic Corrosion. R. H. BROWN. A.S.T.M. Bul. *No.* 126: 21 (Jan. '44). Intensive survey with 24 references. Corrosion of given metal accelerated by contact with some second metals but reduced by contact with others; this action galvanic corrosion. Wt. loss by anodic metal in electro-chem. process proportional to current between anodic and cathodic areas. Total current comprises sum of local currents on anode between anodic and cathodic areas, and current between anode and cathode electrodes. Extent of galvanic corrosion dependent on potential difference, polarization, current distr., resistance of environment and metallic circuit and other factors. As electro-chem. series based on thermodynamic concns. of unity, it cannot predict potentials in general case nor acceleration of corrosion by contact. Potential measurements show that composition of soln. may det. which of 2 metals is anodic or cathodic. Reduction of potentials with current density on electrodes termed polarization. Wt. loss of iron specimens coupled with copper, nickel and lead in 0.1 M salt soln. acctd. for by means of polarization current diagram. When cathodic polarization governs rate of corrosion as with iron-copper, couple corrodes under *cathodic control*. Polarization diagram substantiates corrosion of zinc-copper couples in salt solns. independent of area of zinc, but proportional to area of copper. Cadmium and tin coupled with zinc behave somewhat similarly, but latter particularly modified by anodic polarization. This condition termed *mixed control*. *Anodic control* approached under some conditions where anode area small compared to cathode area. If neither electrode polarizes appreciably, corrosion current, hence corrosion rate, controlled by ohmic resistance of liquid and metallic circuits; when separated zinc and copper couple may corrode under *resistance control*. Corrosion of most metals and alloys usually less when functioning as cathode of a couple than when exposed alone. Since soln. around cathode becomes basic, amphoteric metals, such as aluminum, zinc and lead, may corrode as cathode if current density high. Galvanic corrosion may be alleviated by (1) more careful selection of alloys, (2) insulation of contacting alloys, (3) painting, and (4) cathodic protection.—*A. A. Hirsch.*

War Production Board—Office of War Utilities

Administrative Letter to All Electric, Gas, Water and Communication Utilities—October 18, 1944

TWO-WAY MOBILE RADIO EQUIPMENT

A SMALL quantity of two-way mobile radio transmitting and receiving equipment has been made available recently for installation by electric, gas, water and communication utilities. We are therefore in a position now to act favorably on applications (WPB-2774) for such equipment, up to the limit of the quantity assigned, where there is an important need for the equipment.

Because of the limited quantity of this equipment available for distribution to utilities, it will be possible for us to approve applications only in those cases where a real need exists. Applications should not be submitted unless the applicant is able to demonstrate that the radio installation will make possible substantial savings of manhours and truck time and travel, substantial improvement in system operation or substantial increase in reliability of local service to consumers.

Applications for the necessary licenses to operate two-way radio equipment should be filed with the Federal Communications Commission concurrently with filing applications with the War Production Board for preference ratings. Applications to the War Production Board will not be approved until after the Federal Communications Commission has assured us that licenses for the installation will be approved.

(Signed) EDWARD FALCK
Director
Office of War Utilities